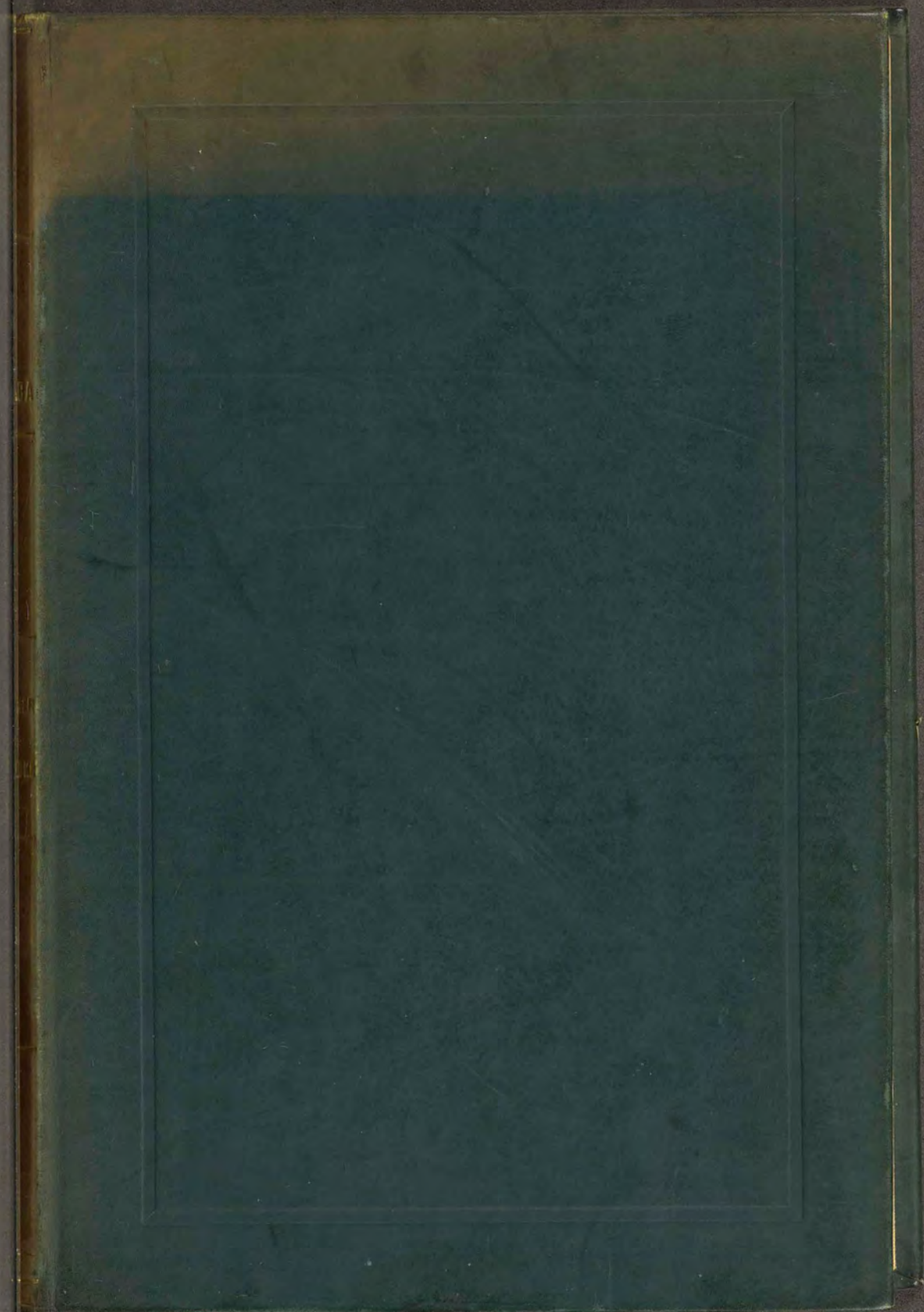
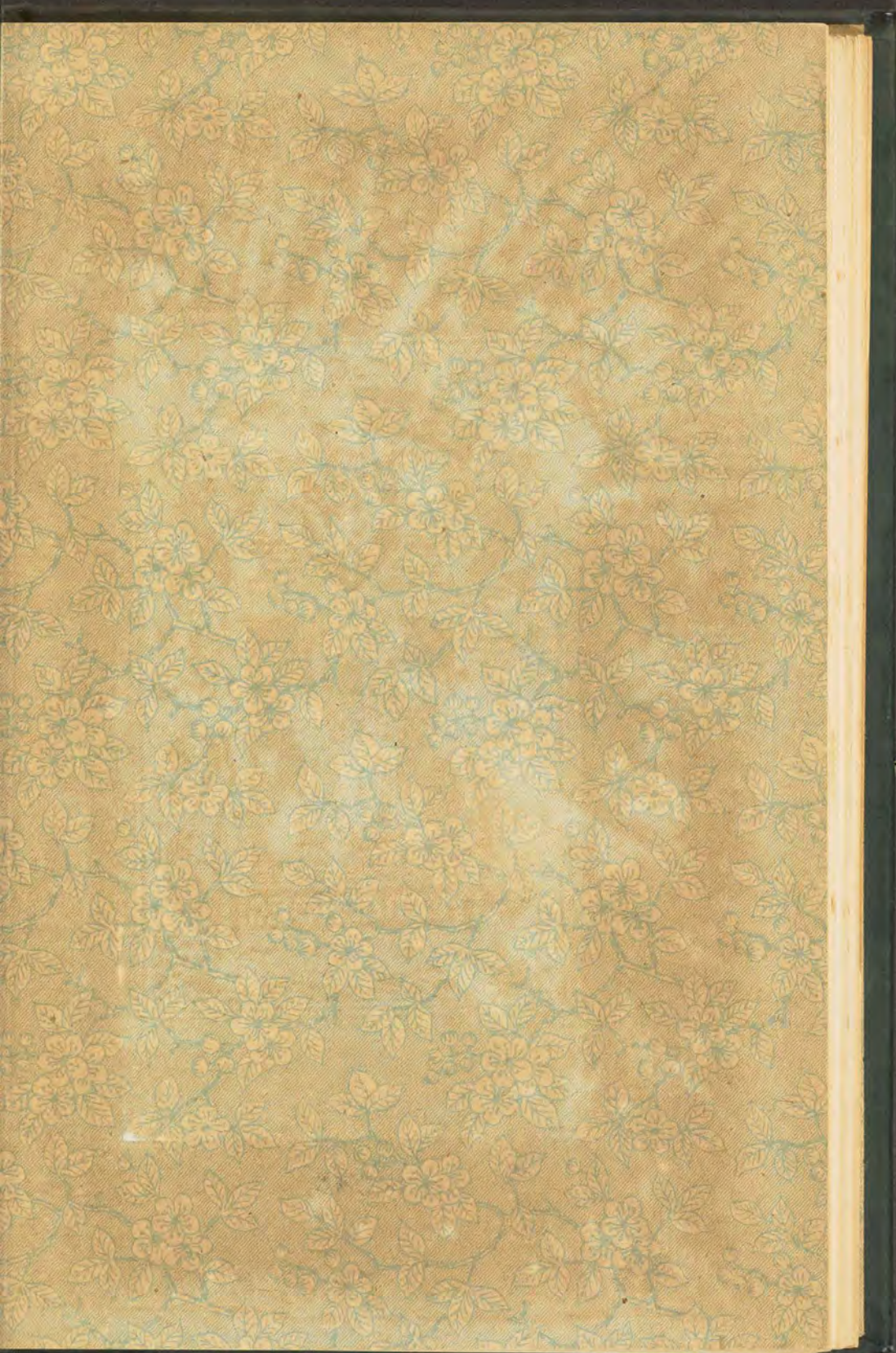




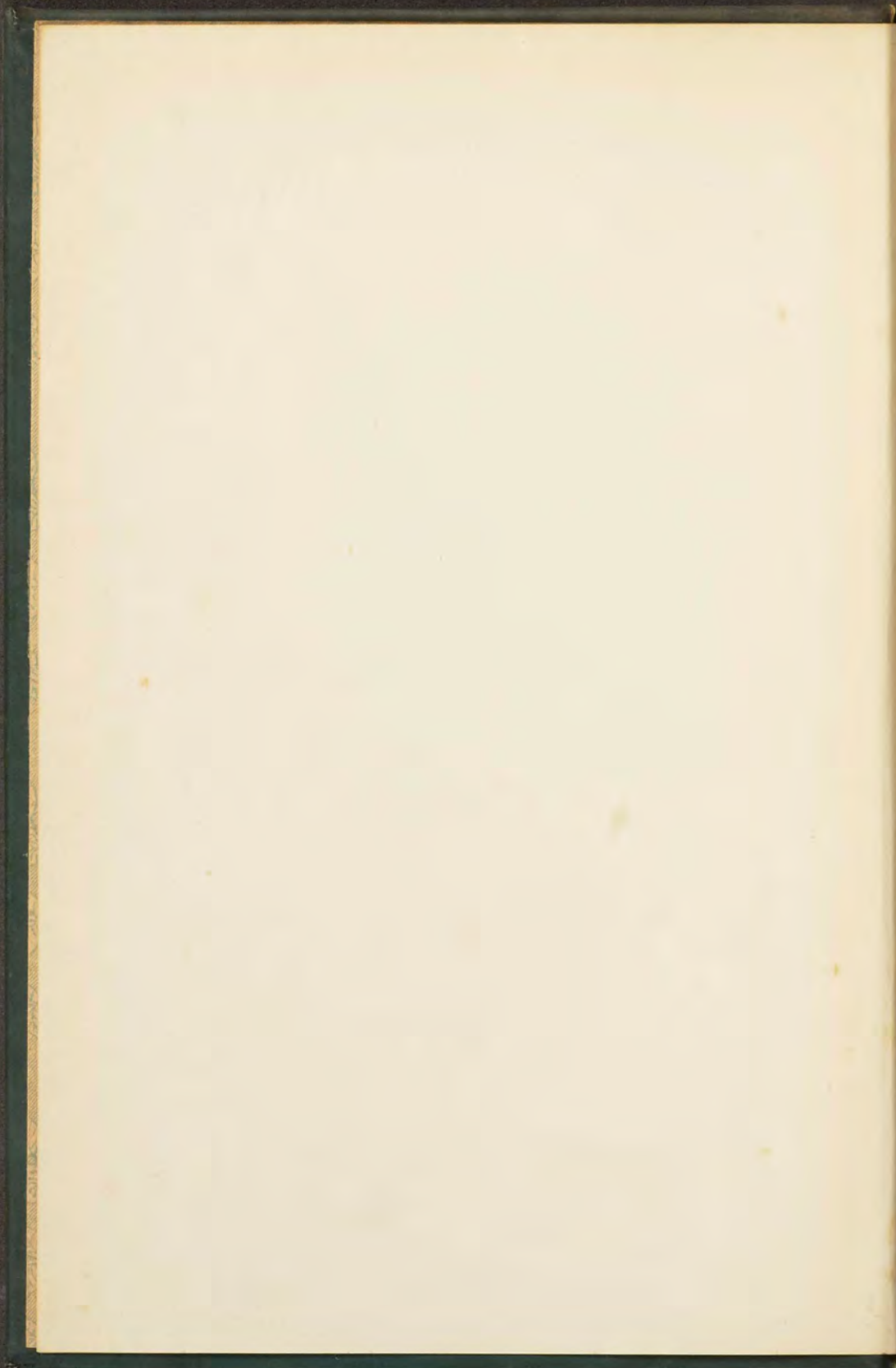


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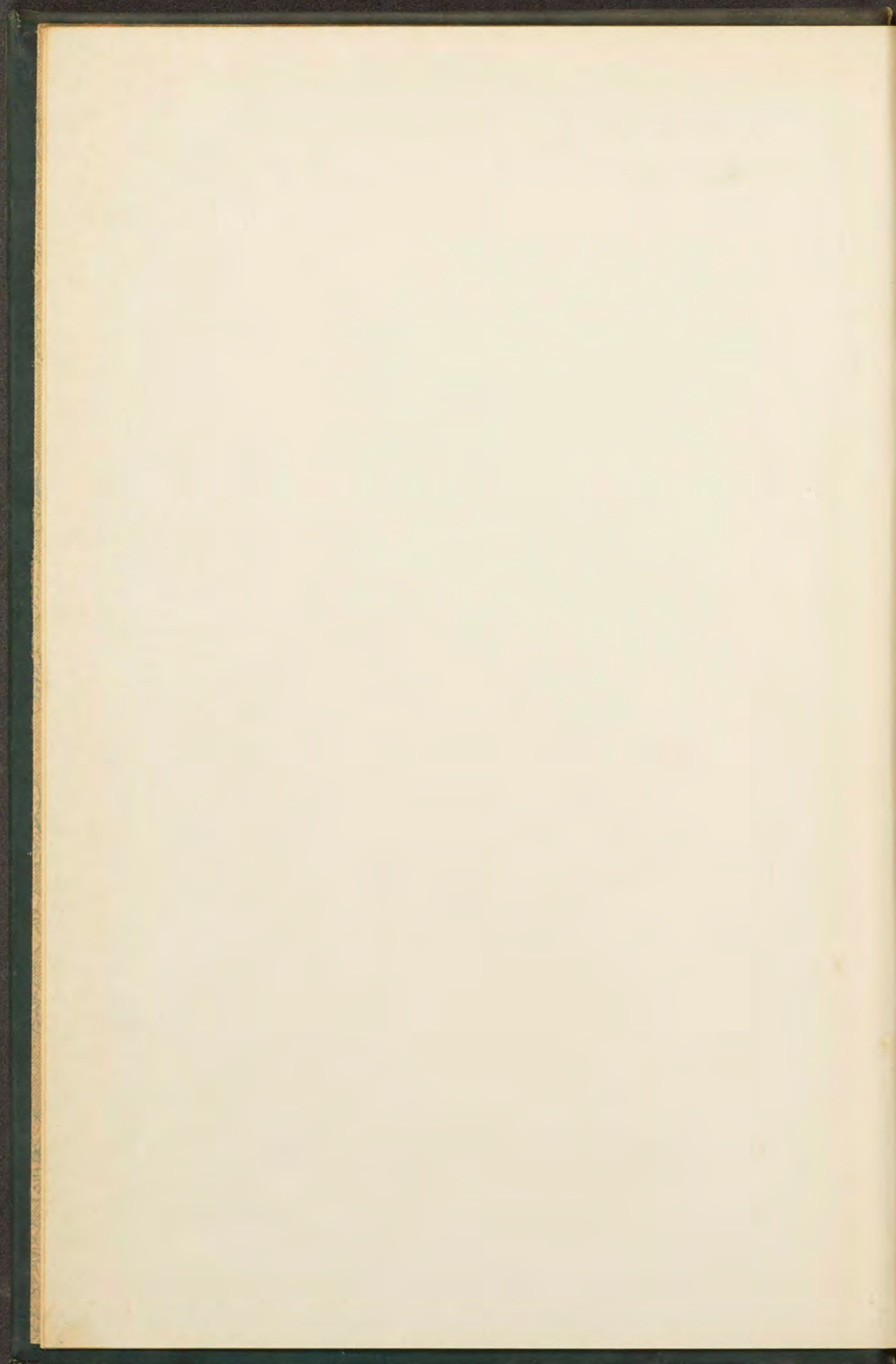
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MINERAL DEPOSITS

OF THE

Union of South Africa

Edited by
PERCY ALBERT WAGNER
and
LEOPOLD REINECKE



PRINTED IN SOUTH AFRICA
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Foreword

The rise of the Union of South Africa to prosperity, and, indeed, to national importance during the past fifty years has been due in no small measure to the discovery and development of its minerals. The value of the mineral production during this period has amounted to about £1,500,000,000, ninety per cent. of which is in respect of gold and diamonds. The output is to-day on as high a level as ever, being at the rate of nearly sixty million pounds per annum for precious metals and precious stones, while other minerals to which greater attention is now being devoted add a further six million per annum.

In view of the importance to the world of the mineral wealth of South Africa it is fitting that the Third (Triennial) Empire Mining and Metallurgical Congress should take place here this year. The Congress will be attended by members from all parts of the world, and this review of the mineral resources of the Union is published by the executive committee responsible for the organization of the Congress in order to place before members in as concise a form as possible the present position and prospects of the mineral industry of the country.

The compilation of this volume was first undertaken on behalf of the Committee by Mr. F. L. Bosqui who died in May, 1929, before material progress had been made. The work was subsequently taken in hand by Dr. P. A. Wagner, and a great deal of material was gathered together by him, but unfortunately his death in November, 1929, occurred before he had been able to give form to the book. In this emergency Dr. L. Reinecke came to our help, and

the thanks of the Committee cannot be adequately expressed to him for his invaluable aid, without which this volume could not have been produced in time for the Congress. With great energy and ability he has produced it in less than three months, no mean achievement when it is understood that Dr. Reinecke was not able to give his undivided attention to this work as he had to carry on his own profession of consulting geologist.

If, therefore, there are any shortcomings in the volume readers will understand that they are due to the extreme pressure under which this work has had to be carried out.

In his editorship Dr. Reinecke has been ably assisted by numerous writers, to whom suitable acknowledgment is made.

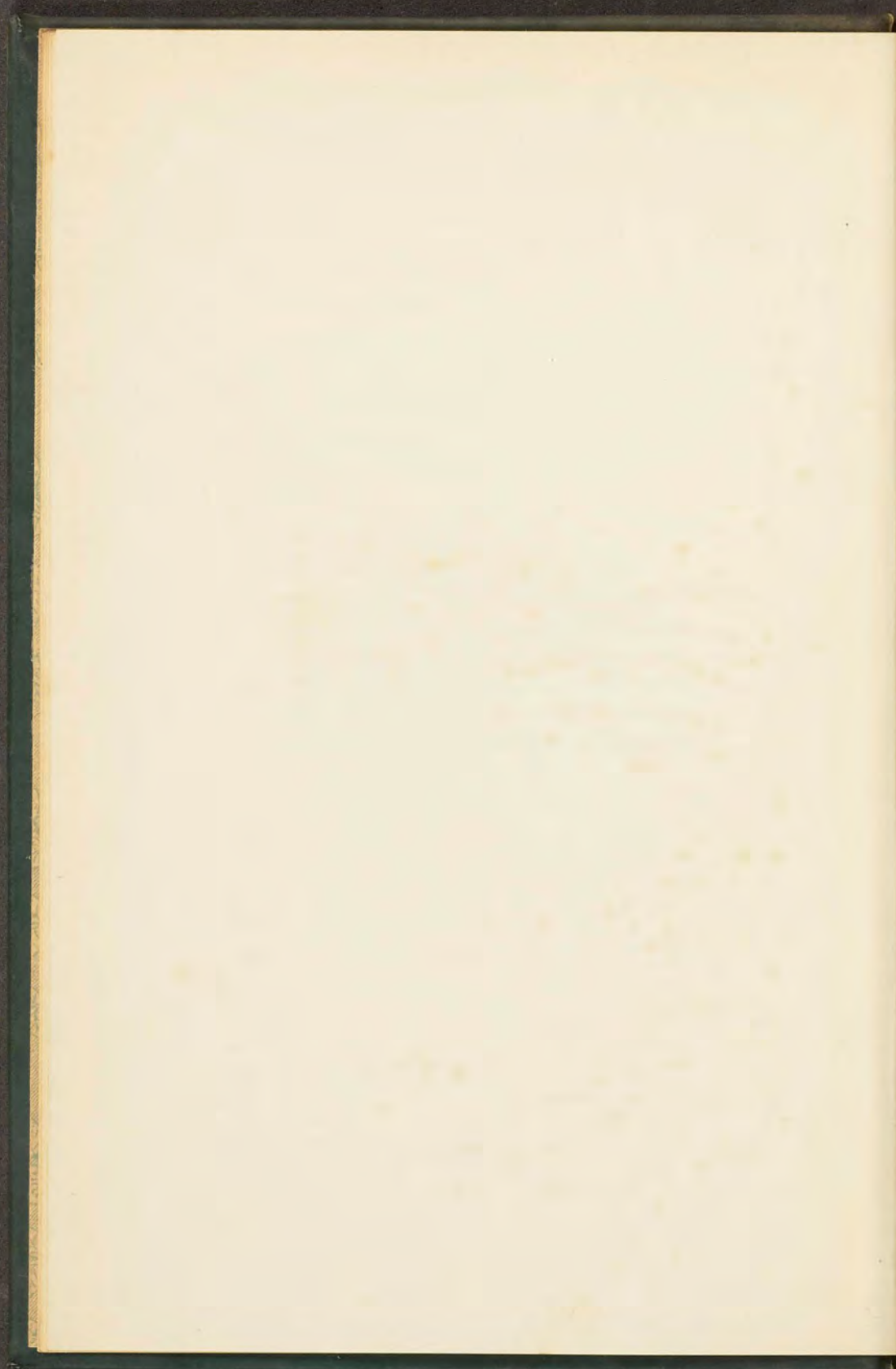
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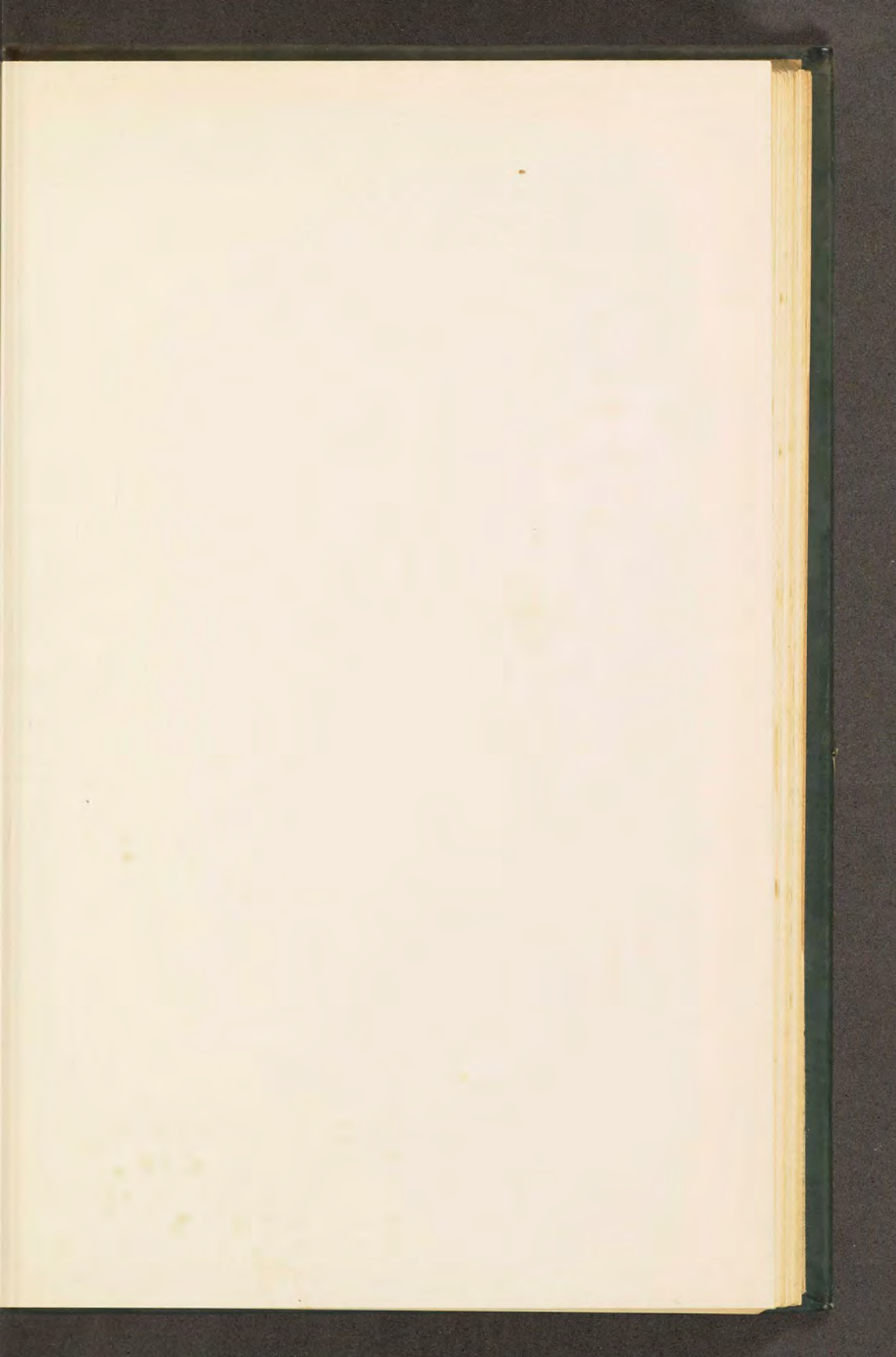
Chairman, Executive Committee.

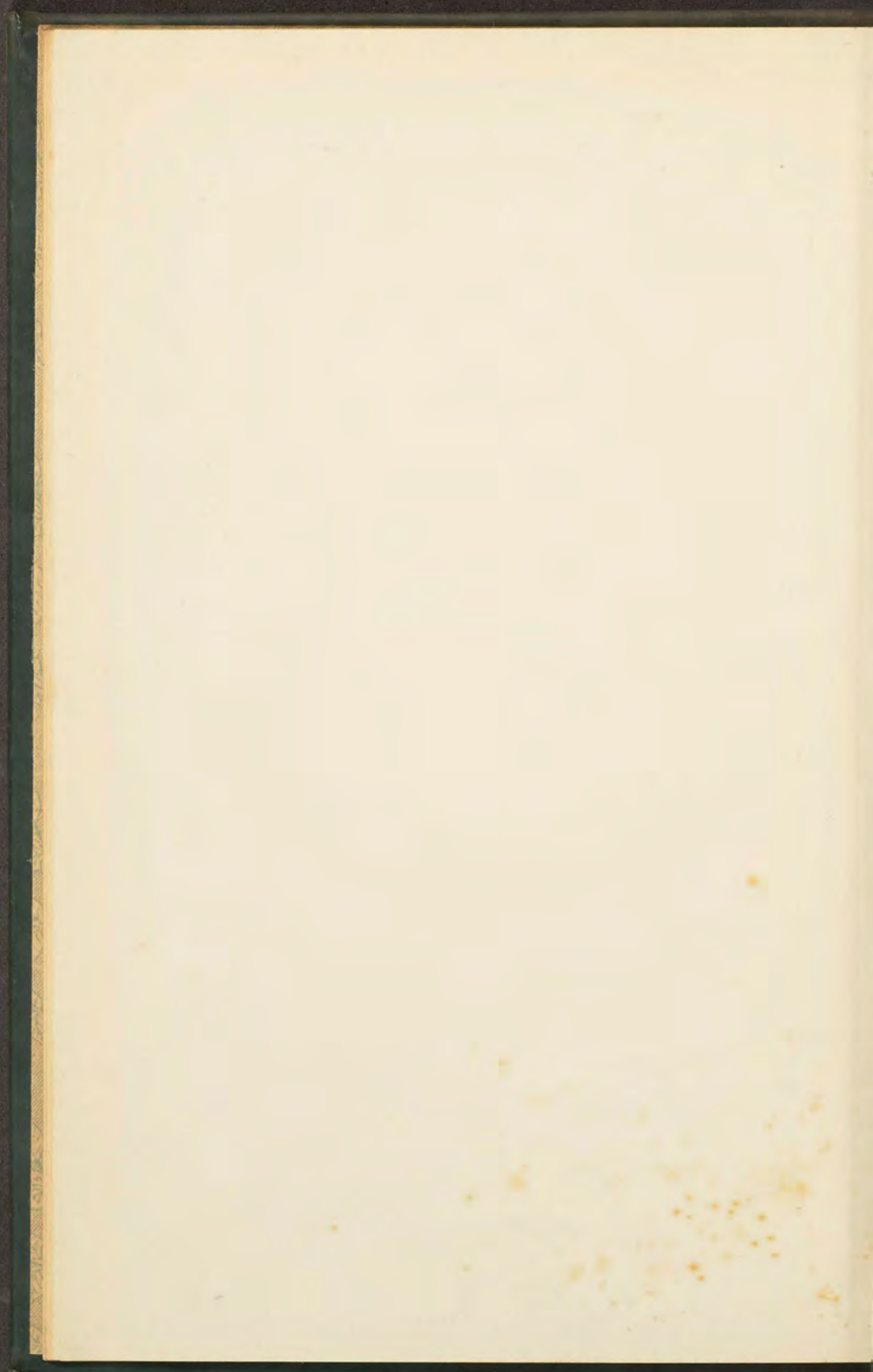
Johannesburg.

February 25, 1930.

The Executive Committee of the Third (Triennial) Empire Mining and Metallurgical Congress desires to express its indebtedness to the Finance Committee of the British Empire Exhibition (South African Section) for the grant of £500 towards the publication of this volume.







Mineral Deposits of the Union of South Africa.

Edited by PERCY ALBERT WAGNER and LEOPOLD REINECKE.

Preface

In this book an attempt has been made to collect into one volume the more important facts in regard to the mineral deposits of the Union of South Africa. Its compilation was interrupted by the death of the editor, Percy Albert Wagner, in November, 1929. The work is nevertheless very largely Wagner's for the description of by far the larger number of ore deposits is taken from his publications. Extracts have been taken, verbatim in many cases, from the section on economic geology, contributed by Wagner to *The Geology of the Union of South Africa. Handbuch der Regionalen Geologie*, Band VII, 7a. The chapter on diamonds is based on his classical work *The Diamond Fields of Southern Africa* (The Transvaal Leader, 1914); the section on iron ore on *The Iron Ore Deposits of the Union of South Africa*, Geological Survey, Memoir 10, Pretoria, 1928; and the chapter on platinum on *Platinum deposits and Mines of South Africa* (Oliver & Boyd, Edinburgh, 1929). As a member of the Geological Survey and at other times as a consulting geologist and engineer he has examined and reported on practically all the important mineral deposits of South Africa. A thorough early training together with broad reading and tireless devotion to his calling kept him in touch with the latest thought in geological science, so that many of his publications have proved to be outstanding contributions to the science of ore deposits. The student of the mineral deposits of South Africa is referred to a bibliography of Wagner's work which is to appear within a short time in the *Transactions of the*

Geological Society of South Africa. Other papers on South African minerals and ores are to be found in the publications of the Geological Survey of the Union of South Africa, Pretoria, and in the *Transactions and Proceedings of the Geological Society of South Africa*, Johannesburg. For general geological information these publications and *The Geology of South Africa*, by A. L. du Toit (Oliver & Boyd, Edinburgh, 1926) should be consulted. Papers dealing with problems in mining and metallurgy are to be found in the *Journal of the Chemical Metallurgical and Mining Society of South Africa*, Johannesburg, and in the reports of the Government Mining Engineer. The references given at the end of chapters are not intended to serve as complete bibliographies. A bibliography and a subject index of South African geology by A. L. Hall were published by the Geological Survey of the Union of South Africa, Pretoria, as Memoirs 18 in 1922 and 22 in 1924, respectively.

Acknowledgements are due to A. W. Rogers, who has contributed the chapter on topography and geology, G. A. Watermeyer and S. N. Hoffenberg, the section on mining methods on the Rand, A. King, the section on the extraction of platinum from its ores, W. J. Gau, the section on mining and ore reduction in the Barberton District, L. T. Nel that on manganese, T. Coulter the chapter on coal and C. J. N. Jourdan, special articles on the base metals and non-metallic minerals. Other contributors were B. G. Orpen, K. J. MacWilliam, J. Thorland, J. Innes, K. Richardson, J. A. Woodburn and W. Kupferburger. Assistance was rendered in revising manuscript by R. S. G. Stokes, C. J. Grey, H. A. White, V. C. R. Brereton, A. L. Hall and N. McClure, and in proof-reading and composition by H. C. Hopkins. Special thanks are due to F. C. Vaughan, of the Department of Mines, who wrote the section on accidents on mines, prepared most of the tables, and revised the figures. Other acknowledgements are made in the text and as footnotes.

L. R.

February, 1930.

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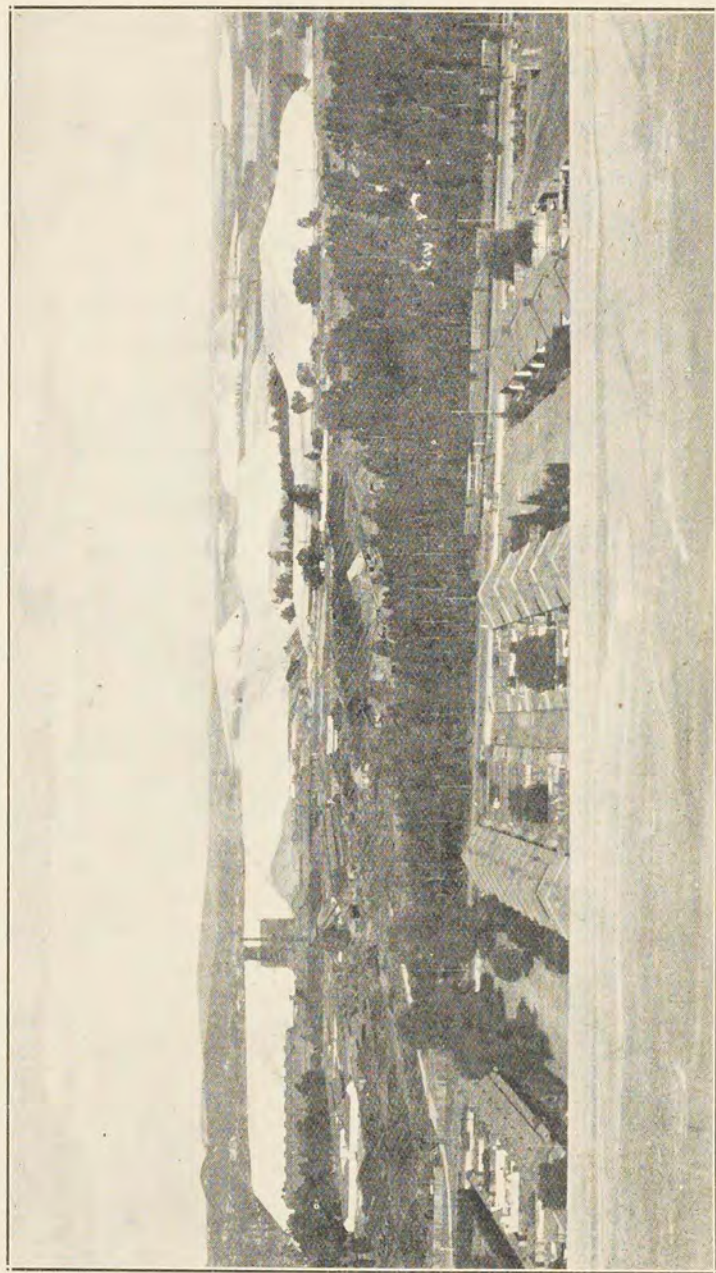
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The Central Rand looking east from the Ferreira Deep mine, south of Johannesburg.

[Photo, S.A.R. Publicity Dept.]

CHAPTER I

CHARACTER OF THE COUNTRY

By A. W. Rogers¹

The Union of South Africa occupies an area of 472,347 square miles at the southern extremity of Africa. It is, therefore, only about one-eighth the size of Canada and one-sixth that of the United States and Australia. Its northern and southern extremities lie between latitudes $22^{\circ} 10'$ and $34^{\circ} 50'$ South, so that except for a narrow strip along its northern boundary it is all within the temperate zone. On three sides it is swept by the ocean, while along an irregular boundary to the north lie the territories of South West Africa and Bechuanaland, Southern Rhodesia and the Portuguese Colony of Mozambique.

Of the four provinces that comprise the Union, the Cape of Good Hope, forming the end of the continent, is larger than the others combined. From its north-eastern boundary the Orange Free State, Natal and the Transvaal project northward. The Transvaal, which lies the farthest north, occupies less than one-fourth of the total area of the Union, and is by far the richest in mineral wealth. It has produced nearly 80 per cent. of the total value of the mineral output of the Union, and possesses very large reserves of gold, coal, iron and other ores.

TOPOGRAPHY

South Africa is predominantly a land of plateaus and mountains, and probably 90 per cent. of its surface lies over 1,000 feet above the level of the sea (see contour map inset). Lying roughly parallel to the coastline and from 50 to 200 miles inland, there is a long line of sea-facing escarpment (Figure I). Within this rampant the topography, though diverse, is dominantly high plateau. Between the escarpment and the ocean is a tract of country that is, on the whole, of lower elevation than the plateaus inland from it, but varies very greatly in its character. The escarpment, which can be followed northward up the west coast of Africa as far at least as the Congo, includes the Kamiesberg, Bokkeveld, Roggeveld, Nieuwveld, Sneeuwberg and Stormberg ranges of the Cape Province and the Drakensbergen of Natal and the Transvaal.

The highest parts of the country lie on or near the edge of the eastern and south-eastern line of escarpment, and it

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is only in the Folded Belt of the south that the ground on the seaward side of the escarpment rises in places to greater heights than the escarpment itself.

Although the highest point in the sub-continent, Giant's Castle in Basutoland, is only 10,880 feet above sea-level, 38 per cent. of the area of the Union lies above the 4,000 feet contour.

The greater portion of the interior plateaus area is drained through the vast basin of the Orange River westward into the Atlantic, while the northern section of the Transvaal high country drains via the Limpopo into the Indian Ocean. The belt on the seaward side of the escarpment is drained by comparatively small river systems whose headwaters have, except in the northern Transvaal and a few other places, not cut their way back far beyond that great wall. All of the rivers flow over comparatively steep gradients, but there are short reaches of quiet water at the mouths of some of those that flow into the ocean on the south-eastern coast.

There is a regional slope from the higher country near the eastern and south-eastern line of escarpment down to a broad, comparatively low belt that stretches from the lower reaches of the Orange River valley north-eastward through the Kalahari desert. From this belt the general elevation rises again north-eastwards to the highlands of Windhoek.

THE INTERIOR PLATEAUS

The Interior Plateaus region has been divided into the Upper Karroo, Highveld, Basuto Highlands, Kaap Plateau, Middleveld, Bushveld, Limpopo Highlands, Namaqua Highlands and Bushmanland-Kalahari district (Fig. 1). The region includes many different types of topography: plateaus and mountains, well watered country and semi-desert. A very large portion of this area, however, is underlain by nearly flat-lying rocks, and its topography is plain-like with comparatively low hills rising from the general flat surface. Of this nature are the Upper Karroo and Highveld, a vast series of uplands of average elevation from 4,000 to 6,000 feet underlain by nearly flat-lying rocks of the Karroo geological system (Plates I. and II.). Of this type also are portions of the Kaap Plateau, of the Middleveld, and of the Bushveld of the Transvaal, in which flat-lying rocks of various systems underlie wide plains.

In the Basutoland Highlands the headwater streams of the Orange River have carved rugged mountains out of the



upper beds of the Karroo system. This is the highest ground in the country, much of it lying over 8,000 feet above sea level (Plate III.).

The Kaap Plateau consists of flat plains traversed by north-south ranges of hills and mountains. The Langebergen on the west rise to over 6,000 feet; the flat country is over 4,000 feet above sea-level (Plate IX.).

The Middleveld of the Transvaal includes plains, hilly country of low relief and long parallel ridges along its northern border. It is drained by the Vaal and Limpopo Rivers, and most of the country is over 4,000 feet above the sea (Plate X.).

The Bushveld consists of flat and undulating country surrounded by roughly concentric ridges formed by a series of rocks that dip from the margins of this district inward toward its central portions. The view in Plate IV. is taken from comparatively flat ground within the Bushveld looking northward toward the outer ring of encircling ridges.

The area called Limpopo Highlands includes the extremely rugged heights of the Transvaal Drakensberg, the Zoutpansberg and Waterberg, and with these the Pietersburg and Waterberg flats to the west (Plate XI.). The Transvaal Drakensbergen, traversed by deep and rugged gorges, well watered, and in part covered with forest, afford magnificent scenery. The Waterberg flats, on the other hand, are semi-desert sand-covered areas, which grade into the Kalahari desert to the west and the low ground of the Limpopo to the north. Elevations in the Limpopo Highlands range from 3,000 feet in the west to 7,000 feet in the mountainous country toward the north-east and east.

On the western side of the Interior Plateaus are the Namaqua Highlands and the Bushmanland-Kalahari area. The Namaqua Highlands, which stretch northward into South West Africa, are part of the mountainous western edges of the interior plateaus. The region is characterized by a scanty soil and rugged ground along its western edge, with rolling, and in part plains, country to the east. The portion of the Namaqua Highlands that lies near the Orange River is very dry, but there are areas in the extreme south and farther north in South West Africa that receive enough rainfall to make stock farming possible. Except where traversed by the Orange River, this area lies between elevations of 2,000 and over 4,000 feet (Plate V.).

The Bushmanland-Kalahari area is a region covered for the most part with a thick layer of sand forming vast flat plains through which rise steep-sided hills of the island

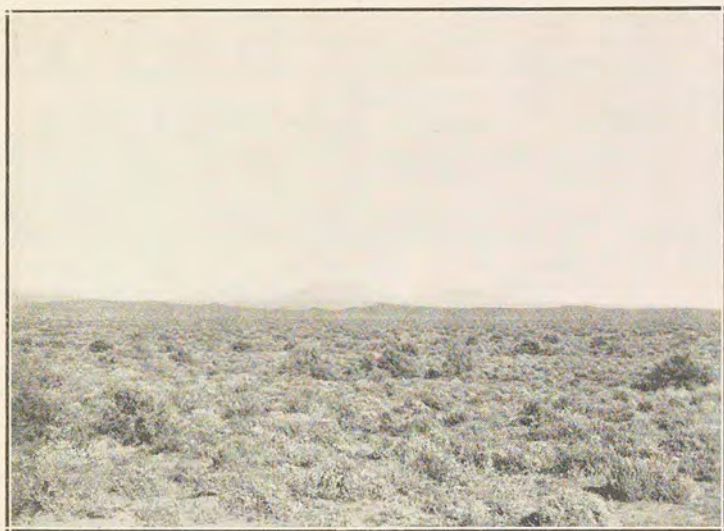


Plate I.—Plateau of the Great Karroo near Calvinia with flat lying Ecca beds and dolerite dykes and sills.

[Photo, A. W. Rogers.]

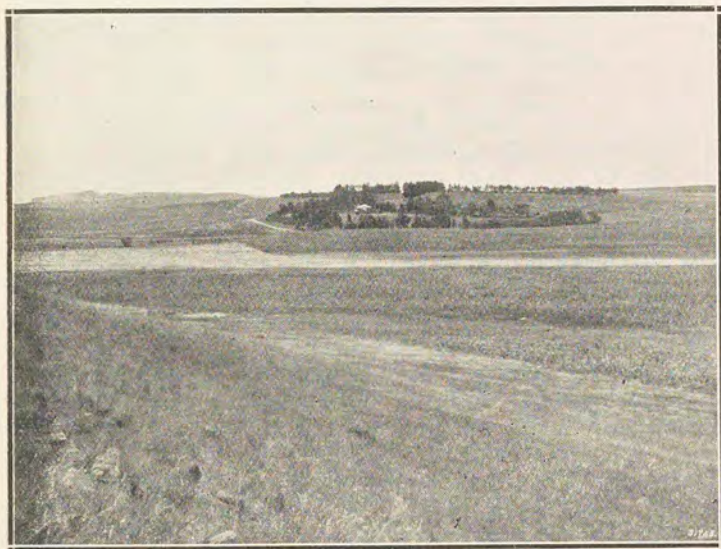


Plate II.—Grass country in the Highveld near Bethlehem, O.F.S. The distant hills are of Stormberg beds and lie near the Great Escarpment.

[Photo, Publicity Dept., S.A. Railways.]

type (Plate VI.) Outside of the Orange River itself, which derives its water from the eastern high plateaus, there is no surface water in this district.

The Kalahari proper is a region of sand dunes that in many places occur in remarkably parallel ridges (Plate XIV.) Outside of the Korannabergen and Langebergen ranges on its south-eastern border, it is a region of comparatively low relief lying between elevations of 2,000 and 4,000 feet.

OUTSIDE THE ESCARPMENT.

The country on the seaward side of the escarpment is very diverse in topographic character. It is separated on the map (Fig. 1) into Low Country or Lowveld, South-eastern Region, Great Karroo, Folded Belt and the Coast Belt. The Lowveld includes an area of comparatively low relief in the northern Transvaal and the exceedingly rugged Barberton mountain land where mountain peaks rise to elevations of over 5,000 feet. It is drained by the Limpopo, Crocodile and other rivers.

The South-eastern Region, which lies south of the Low Country, is for the most part an area of terraced landscapes. The rivers rising in the escarpment flow over steep grades through this region to the Indian Ocean, and have in places cut deep gorges. Hard sheets of dolerite in the flat-lying sediments cause waterfalls and local development of mature river topography above such obstructions (Plate VII.).

The Great Karroo lying between the plateau of the Upper Karroo and the Folded Belt is formed of broad flats broken by long lines of ridges which increase in number toward the south, where it merges into the Folded Belt (Plate XIII.). Elevations range from 1,000 to 4,000 feet above sea-level.

The Folded Belt includes the mountain ranges in the south and south-west of the Cape Province and the wide valleys that lie between them. There is a broad east-west series of ranges and another that trends north-north-west. To the eastward the ranges are cut off by the coast (Fig. 1), but before reaching that line they tend to decrease in height and in the amplitude of the folds. The western series of folds die out toward their northern extremity. The region ranges in elevation from near sea-level to 7,627 feet on the highest point in the Zwartberg range, just west of where it is traversed by Gouritz River. The mountains are rugged and Alpine in their character (Plate XII.).

Remnants of former plains lie between the southern ranges in the form of terraces and table lands with elevations up to 2,500 feet.

The Coast Belt includes a narrow fringe of country along the ocean. The coast is generally low and shelving, or it may be backed by low cliffs behind which the ground rises gradually in places (Plate VIII.). Low, flat-lying coastal plains occur only along a comparatively short stretch, as near Capetown and in northern Zululand. There are bold cliffs on the shore of the ocean in a few places, such as Cape Point, where they rise to a height of 800 feet over the beach. The coast line is remarkably straight, with only a few promontories, which, however, afford very little shelter to shipping. The mouths of certain drowned valleys form natural harbours, but in most cases their mouths are closed by a sand bar. The best harbour is Saldanha Bay on the west coast. For all practical purposes it may be said that the Union possesses no navigable rivers.

CLIMATE AND RAINFALL

The mean annual temperature of various parts of the Union of South Africa corresponds to that of places in Europe which lie from 7 to 10 degrees in latitude farther from the Equator. There is a remarkable uniformity of mean annual temperature throughout the country. This is due to a number of causes: the comparatively high elevation above sea-level of all but the coastal belt; the comparatively small land area which permits the winds from the vast surrounding oceans to exercise a moderating influence over the land temperatures; a cold ocean current flowing up the west coast; and the cooling rains which fall on so large a section of the country during the hottest seasons of the year. Thus the mean annual temperature of Johannesburg, elevation 5,750 feet, and latitude $26^{\circ} 11'$ S, on the Highveld is 60.6° Fahr., and of Capetown at sea-level, latitude $33^{\circ} 56'$ S, is 62.6° Fahr. The recorded extremes in mean annual temperature vary from 54.7° to 73.1° Fahr.

The mean range of temperature between the hottest and coldest months of every year varies from about 6° Fahr. on the west coast to 29° on the high plateaus of the interior. The daily range of temperature, which is so necessary to the health of Europeans, also increases from the coast to the interior, and varies from 10° to 16° Fahr. at the coast to about 31° Fahr. on the interior plateaus.

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The hottest months are December to February, during which maximum temperatures of 90 to 95 degrees Fahr. occur frequently and up to 100 Fahr. occasionally. Periods of high temperatures last a short time only, and are usually broken by thunderstorms. The highest temperature recorded is 125° at Main (Jan., 1903). Freezing temperatures are encountered during June and July along the escarpment and adjoining high plateaus in the northern Transvaal, Free State, Basutoland and the central parts of the Cape Province. Also in portions of the Folded Belt near the south coast. The coldest spell recorded was in July, 1926, when many stations on the high plateau areas registered below 10° Fahr., the minimum recorded being 5.6° Fahr. at Carolina, Transvaal. Snow falls on the mountains of the Folded Belt and the escarpment of Cape Province every year, and less often on the high plateaus of the north.

In South Africa the greatest average rainfall over broad areas is that along the south-east coast of Natal and Zululand, where the average precipitation is between 40 and 50 inches per annum. A narrower strip of high rainfall follows the Drakensberg escarpment from Swaziland north, and is continued into the Zoutpansbergen. These two areas form a nearly continuous belt, and westward from it there is a gradual decrease in rainfall to a broad belt of average annual rainfall of 10 to 15 inches that stretches from a few miles north of Port Elizabeth to Kuruman and Vryburg. From there west to the Atlantic Ocean the average is from 5 to 10 inches, and in places less than 5 inches. North of Swaziland the rainfall also diminishes from the Drakensbergen eastward to Portuguese territory. The Folded Belt of the south enjoys, except for a few localities, a high average rainfall of from 20 to 40 inches, but there is a sharp drop in rainfall to less than 10 inches in the country lying directly north of the southern and east of the western ranges.

A few small areas in Zoutpansberg and Lydenburg district of the Transvaal, in the Amatola mountains of the Eastern Province, on Table Mountain, and in the Folded Belt near Capetown get over 70 inches of rain per year.

The driest area in the country is along the west coast from Port Nolloth north into the Namib desert of South West Africa, where the average is less than 2 inches.

Except for a narrow strip of country on the west and south coasts, South Africa gets most of its rainfall in the summer months from October to March.

VEGETATION—FAUNA—INHABITANTS

There are comparatively small areas of dense high timber forests in places where the rainfall averages from 40 to 70 inches. These are found at intervals in the Folded Belt north of Cape Town and along the south coast, in the South-eastern Region, and along the Escarpment as far as Zoutpansbergen. The general vegetational covering of the Folded Belt of the south is that of small leaved shrubs and bushes, with some trees in the kloofs.

Along the Coastal Belt of the east coast, with a rainfall of 30 to 50 inches, the country is covered with dense bush—isolated evergreen forests, tall grasses, palms and mangroves. The vegetation is sub-tropical and becomes tropical towards the north.

Grassland covers practically all the eastern half of South Africa wherever the rainfall exceeds 15 inches. Close growing grass lands with few trees, i.e., "steppe" country, characterizes the Highveld (Plate II.) and parts of the Middleveld. Grass associated with scattered bush and tree growth forming "savannah" covers most of the Bushveld, Limpopo Highlands, South-eastern Region, Middleveld and Kaap Plateau. (Plates IV and XI.) In the Karroo, Namaqua Highlands, and part of Bushmanland where the rainfall is from 5 to 12 inches small leaved shrubs scattered over the landscape are the characteristic vegetation with a few hardy trees in the river bottoms. (Plates I, V and XIII.) The Kalahari area north of the Orange River carries grasses that grow in scattered bunches (Plate XIV) with an increasingly abundant growth of shrubs and trees as one proceeds northward. In the western Coastal Belt which is in part a true desert, a few succulent and other desert plants are found, but vegetation is absent over miles of country.

South Africa is noted for the variety and former abundance of its animal life, over 400 species of mammals having been recorded. There is a greater variety of species of birds than in Europe, and about 400 species of reptiles have been classified. In former years great herds of antelope and other beasts roamed the plains, but the game is being decimated and at the present rate of destruction will in a short time have disappeared.

The estimated population of the Union in 1928, based on the last two censuses, is 1,738,937 Europeans and 6,038,646 non-Europeans, or a total of 7,777,583.

Arranged according to numbers the European population is of Dutch-French Huguenot and British descent. From

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

4 to 5 per cent. are of the Jewish race, and all others together form a very small proportion of the population. Fully 87 per cent. of the non-Europeans are of the Bantu race, about 3 per cent. Asiatics and the remainder of other and mixed races.

The northern end of the coast belt in Natal and Zululand, the area embraced in the Low Country (fig. 1) and portions of the northern Transvaal are malarial during the summer months. All the remainder of the Union of South Africa has a healthy climate that is eminently suited to the breeding of a vigorous race of Europeans.

Of a total of 2,025,124 adult males in the Union in 1927, 39,973 Europeans and 313,943 non-Europeans, or a total of 17 per cent. were engaged in mining.

GEOLOGY.

The stratified rocks which build up the territory of the Union have been divided up into the systems and subordinate groups, tabulated at the end of this chapter, and in this table there is a statement of the chief earth-movements and phases of igneous activity so far recognized as having affected this country during the period represented by the succession of sedimentary rocks.

There is still much uncertainty on some of the main points in the geological record of South Africa, especially in the correlation and determination of the relative age of the more ancient sediments and of the great intrusions of granitic rocks in them. Up to the present time no fossils older than those of Devonian age have been determined with certainty, and therefore it is from the structure and character of the rocks themselves that the history of the greater part of the South African strata has to be deciphered.

Beds of proved marine origin are restricted to the margin of the sub-continent, and they are thin compared with the great deposits lacking fossils of marine habit, and in the case of the Karroo system abounding in evidence of deposition under fresh-water or continental conditions.

Owing to the want of well-determined fossils in the rocks older than the Bokkeveld (Devonian), there is no means of determining the base of the Palaeozoic in South Africa, and that horizon known as the Cambrian, and recognized in the other continents as one of the most important geological bench-marks, has therefore not been recognized here. This circumstance makes a local nomenclature of the older rocks necessary, because the use of such

terms as Archaean or Algonkian, which are widely used elsewhere, is not strictly correct for any South African rocks, and the well-known lower Palaeozoic systems of other continents cannot be identified at all; but the discoveries of Range, Schneiderhöhm, Gurich and Haughton of fossils believed to be traces of sponges *Archaeocyathidae* *Cocclenteratae*, and other animals, raises hope of eventual correlation of the Nama system with foreign beds. The geological systems are described in the following pages, beginning from the oldest and going upward in the succession to the latest formed rocks. The geological map (in pocket) should be referred to.

SWAZILAND SYSTEM

The Swaziland system comprises all sedimentary and volcanic rocks older than, or supposed to be older than, the Witwatersrand beds. According to some authors, all rocks in the country older than that formation should be grouped in this system, but the inclusion of granite and orthogneiss is not in harmony with the rest of the stratigraphical nomenclature used in South Africa. Proved intrusive rocks are therefore excluded from the Swaziland system as from the others. There are highly altered rocks of which the original characters are not known, such as certain granulites and schists in the Kheis series, and these will be placed in the system for convenience. Owing to the restricted range of beds generally acknowledged to belong to the Witwatersrand system, the proper test of age is in fact rarely applicable. Some geologists, such as G. A. F. Molengraaff, to whose work Transvaal geology owes much, recognize altered Witwatersrand strata in rocks here classed in the older system; while others regard the intrusive relation of microlite-granites and gneiss, which in the Witwatersrand area are older than the Witwatersrand system, as decisive in showing that the beds invaded are of pre-Witwatersrand age. This evidence of age can only be accepted in the immediate neighbourhood of recognized Witwatersrand strata, and it does not carry weight in distant areas such as Barberton or Prieska. Thus it becomes clear that the Swaziland system is a convenient class into which very old strata can be placed till satisfactory evidence of their age is found. The system is not comparable with any of the others adopted in South Africa, and the correlation of the various series described below is uncertain.

Moodies Series is the name given to a group of conglomerates, quartzites, slates and banded ironstones in the

Barberton, Wakkerstroom and Piet Retief districts that lie to the north and south-west of Swaziland, and at Mount Maré in Pietersburg. Over large areas these beds have altered by shearing and by acid and basic intrusive igneous rocks; andalusite and ottrelite-schists are abundant, while garnet, sillimanite and corundum are amongst the new minerals in the contact zones, and tourmaline extends through a great vertical range at Mount Maré. The James-town series in Barberton is described as a group of basic schists, chiefly intrusive, with which are associated belts of altered sediments and volcanic rocks. The Onverwacht volcanic series of the same district consists of basic amygdaloids, quartz-porphyrries, tuffs, and perhaps altered dolomites.

In the Pongola valley in the south-eastern Transvaal and neighbouring part of Natal there is a thick group of sediments and lavas, the Lower Pongola Series, followed, apparently unconformably, by the shales, jaspilites, quartzites and conglomerates of the Upper Pongola Series. These are probably the equivalents of Moodies Series and the Onverwacht volcanic rocks.

Near the Orange River, in the divisions of Prieska, Kenhardt and Gordonia, there is a great group of sedimentary and extrusive rocks known as the Kheis Series. It is divided into three sub-groups, the Marydale, Kaaïen, and Wilgenhout Drift beds, which apparently follow each other conformably upwards in the order named. Gneiss is in intrusive contact with all three sub-groups, and large bodies of the Marydale and Kaaïen beds lie entirely surrounded by granite and gneiss. The Marydale beds consist of arkose, lavas of acid and basic composition, tuffs, quartzites of various kinds, including some with very much magnetite in them, limestone, and various schists and granulites. The original nature of some of the granulites is proved by the presence of amygdaloidal structure, but others are of doubtful character. The variety of new minerals developed in these beds is great. Amongst them are pyroxenes, amphiboles, garnet, sillimanite, cyanite, staurolite, and various lime silicates. The Kaaïen beds are quartzites and quartz-schists chiefly, and they form the prominent range of hills on the Prieska-Kenhardt boundary, as well as Scheurberg in the Kalahari. The Wilgenhout Drift beds include slates, acid and basic lavas and tuffs, quartzites and limestones.

The Kraaipan Series of Bechuanaland is older than the Ventersdorp system, but it has not been found to be

penetrated by granite or gneiss. It is composed of banded magnetic quartzites, jaspers, various schists, limestones, and altered acid and basic lavas. The very similar beds of Abel's Kop and Goudplaats described by Jorissen are traversed by offshoots from the neighbouring granite. All these beds present close resemblance to parts of the Kheis Series.

In Gordonias and Namaqualand there are many lenticular masses of schists and quartzites in the gneiss. Sillimanite and garnet are often conspicuous in these rocks and biotite and cordierite are usually present.

Granite and gneiss of later age than the Kheis series and of the rocks which are represented by the fragments of schists in the Namaqualand and Bechuanaland granites cover an area of many thousand square miles in the north of the Cape Province (Plate VI) and the adjoining part of the Transvaal. They are quartz-microcline-orthoclase-biotite rocks as a rule. Amphiboles and pyroxenes are rare. Porphyritic granites are not often seen; pegmatites are abundant. The granites and gneiss of the northern and north-eastern Transvaal, as well as those of the country immediately north of the Witwatersrand, are quartz-microcline-plagioclase-biotite rocks generally and are distinguished from the much younger granite of the Bushveld.

A later, but probably pre-Transvaal, group of intrusive rocks is the Palabora Complex of granite, syenite and pyroxenite, which invaded the older gneiss and Swaziland beds of the Murchison range.

An important and interesting feature in the granitic areas north of Pietersburg and in the Low Veld is the abundance of corundum in pegmatites intrusive in ultra-basic magnesian rocks.

In Namaqualand, a group of small intrusions of rocks, varying from quartz-rocks to nearly pure magnetite, and including pyroxenite, norite, and anorthosite, is of later age than the gneiss and schists, and probably older than the Nama formation. They are of importance on account of the apparently syngenetic copper ores in them.

WITWATERSRAND SYSTEM

The Witwatersrand system is found in the southern Transvaal and the adjoining part of the Orange Free State. In the chief area, near Johannesburg, the system is divided by E. T. Mellor, who mapped it in detail, into lower and upper groups, and these again into five series.



Plate III.—Basutoland Highlands looking across the Orange River valley from Nquatsha's Nek. Cave sandstone overlain by Drakensberg lavas.

[Photo, A. W. Rogers.]

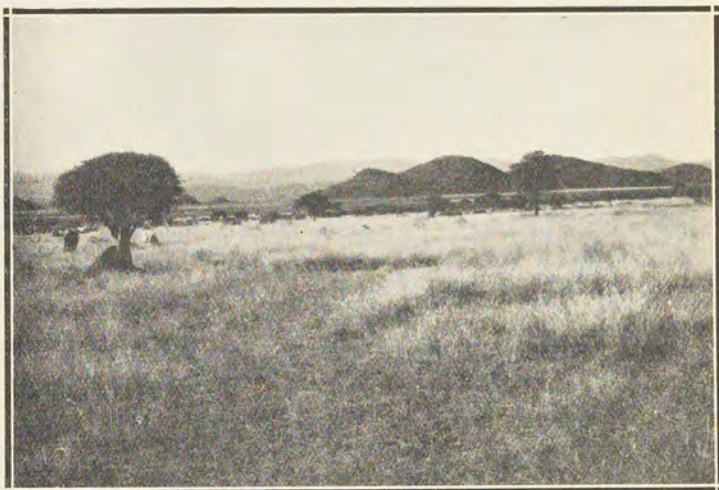


Plate IV.—Looking north towards Chunies Poort, Transvaal Bushveld. Foreground Bushveld granite, in the middle distance kopjes of norite; in far distance ranges of the Pretoria Dolomite and Black Reef series.

[Photo, F. E. Wright.]

The Lower Witwatersrand beds comprise:—

The Hospital Hill series, commencing with the Orange Grove beds, quartzites and shales, which form the conspicuous northern escarpment of the Rand overlooking lower ground towards Pretoria. They rest upon a denuded surface of granite and schists, and are followed by thinly laminated siliceous and ferruginous rocks locally called slates or shales. With these beds are two thin, but remarkably persistent, bands of quartzites, the ripple-marked quartzite and the feldspathic speckled bed. Towards the top of the series are the thick Hospital Hill quartzites, sometimes coloured green, and in parts having large, well-rounded quartz grains set in a finer grained quartzite matrix (sago structure). These quartzites, with the shales interbedded with them, form the ridge immediately north of Johannesburg.

The Government Reef series lies conformably on the Hospital Hill series, but along the Central Rand the beds are for the most part eliminated by strike-faults, a fact which was brought out by Mellor's mapping, and which was responsible for many misunderstandings of the succession of the rocks below the Main Reef group before that map appeared. The series consists of quartzites and shales, some of which are very ferruginous rocks, and thin conglomerate beds which have not been found to be worth mining on a large scale.

The Jeppestown series, red-weathering argillaceous rocks with subordinate sandstones or quartzites, rarely forms good outcrops. It varies in apparent thickness from place to place owing to faulting.

The Upper Witwatersrand group follows the lower conformably, and differs from it in being more arenaceous and in having a greater development of conglomerates. At its base is the Main-Bird series, some 3,000 feet of quartzites with subordinate argillaceous beds and persistent bands of conglomerate, notably the Main Reef group of conglomerates in the lower part of the series, which are the important beds from an economic point of view because they yield almost all the gold won on the Witwatersrand goldfield. In the central Rand there are three reefs of banket—the local name for the gold-bearing conglomerate of quartz pebbles set in a matrix of pyritic quartzite. These are known as the Main Reef, Main Reef Leader and South Reef. The Main and South Reefs thin out eastwards, leaving the Main Reef Leader as the productive reef there, and the Leader disappears westwards. The conglomerates

above the Main Reef group, the Livingstone and Bird Reefs, are thin individually, though numerous, and are not persistent. A band of chloritoid-chlorite rock, known as the Bird Reef marker, lies a short distance above the Bird reefs on the central Rand, and andesitic lava, called the Bird amygdaloid, is on the same horizon in the east Rand and Heidelberg. The Hercules shaft of the E.R.P.M. passes through the two rocks, the amygdaloid being underlain by the sedimentary type. The Kimberley-Elsburg series lies conformably on the beds just described, and at their base is a thick band of argillaceous beds, the Kimberley shales. The Kimberley conglomerates are usually separated from the shales by quartzites, and grits and quartzites some 3,000 feet thick separate the Kimberley from the Elsburg conglomerates. These latter are often large pebbled conglomerates, and in the main area of their occurrence north of the amygdaloids of Klipriviersberg no discordance below them has been detected. The occurrence, however, of very similar conglomerates lying unconformably on Lower Witwatersrand beds at Langerman's Kop and the north side of Bezuidenhout Valley points to the unconformable overlap of the Elsburg beds northwards.

In the Heidelberg district south-east of Johannesburg the thickness of the Witwatersrand system is reduced to 57 per cent. of what it is on the Rand, while the series are reduced to from 30 to 66 per cent. See also Chapter IV.

VENTERSDORP SYSTEM

The Ventersdorp system lies on the Elsburg beds conformably in the Klipriviersberg and Heidelberg, and overlaps the Witwatersrand beds unconformably on the Witwatersrand. In the Ventersdorp region south-west of Johannesburg the unconformity is very marked, inliers of disturbed Lower Witwatersrand beds appearing through the partly denuded course of Ventersdorp sediments and lavas. In the Cape Province it lies on older rocks. It is mainly a volcanic group, and three sub-divisions, the Zoetlief, Kuip, and the Pniel series, have been distinguished by A. L. du Toit, separated from each other by unconformities. The Zoetlief beds are acid lavas, tuffs, quartzites, shales, limestones, conglomerates and flagstones found in Bechuanaland, Prieska, and in the Kimberley rock-shafts. Acid lavas resembling those of the Zoetlief beds occur at Klerksdorp and other places in the Transvaal. The Kuip series has only been recognized near Omdraaisvlei; it consists of basic lavas, arkose, flagstones, lime-

stones and chert. The Pniel series covers a much wider area than the two lower groups in the Cape Province. The lavas of the Pniel series are usually blue or green amygdaloidal diabase or andesite, though quartz-porphyrries also occur, and tuffs and breccias accompany them. Conglomerates, quartzites and other sedimentary rocks often underlie the volcanic beds in the Cape Province. In the Transvaal the Ventersdorp system covers wide areas south and west of the Witwatersrand; amygdaloidal diabase, such as that in the Klipriversberg, plays a very important part in the formation, but there are conglomerates and quartzites as well as fragmental volcanic rocks in it. The Ventersdorp beds are not found under the Black Reef in the eastern Transvaal or the Pietersburg district; in the western and southern Transvaal and the neighbouring part of the Cape there is a close connection between them in their distribution, though there is a marked unconformity separating them.

Near the Orange River mouth in Namaqualand there is a group of folded rocks divided into four series: the Stinkfontein series of quartzites, arkose, thin conglomerates, phyllites, and volcanic rocks is at the base resting on gneiss; it is followed by the Kaigas series consisting of limestone and shales, on which lies the Numees series of tillite, grit, conglomerate, and slates. The tillite is some 800 feet thick and the boulders are made of gneiss, granite, quartz-prophyry, limestone, various other sedimentary rocks and granulites, but no amygdaloidal rocks have been observed in it. West of the Numees beds there is the Grootderm series of slates, lavas, tuffs and limestones, which may be younger than the Numees beds, but their position is uncertain.

These four series when first mapped were considered to be probably a highly folded western part of the Nama system, but work north of the Orange River by H. S. Haughton and H. F. Frommurze has shown that they are pre-Nama and a part of the Konkip formation founded by P. Range in South West Africa and suspected to be of Ventersdorp age. Beyond the fact that they are intermediate in age between the old gneiss and the Nama system there is little to support the correlation, so their relation to better known pre-Nama beds of the Union is quite unsettled. The large intrusion of hornblende-granite, rich in lime-soda feldspar, which forms the mountain south of Kooboos and which is traversed near that place by part of the great escarpment, is later than the four series just

described, but its relation to the Nama formation is not decided. Many dykes of bostonite and camptonite are associated with the Kooboos granodiorite.

In the valley of the Orange River, from 12 to 36 miles above Upington, there are several areas of volcanic and sedimentary rocks known as the Koras series. They rest unconformably on, or are faulted against, the Kheis beds, but they have suffered little from shearing, and in this respect they offer a great contrast to all the other pre-Karoo rocks of the district. The series consists of two groups; the lower, and mainly volcanic, group is overlain unconformably by the upper group, which is composed of conglomerates and sandstones. The volcanic beds are composed of andesite and basaltic lavas and tuffs, and there are intercalations of a red quartz-porphry, probably intrusive, in them. The upper group contains much material derived from both the lavas and the porphyry. The correlation of the Koras series is uncertain, but it is perhaps part of the Ventersdorp system.

TRANSVAAL SYSTEM

The Transvaal system is the most widely distributed of the pre-Karoo sedimentary rocks in the Union, and it also covers very large areas in South West Africa. At its base is the Black Reef series, a group of quartzites and conglomerates with intercalations of shales. In Vryburg there are also volcanic rocks interbedded with the Black Reef, which, on account of their close resemblance to the underlying Ventersdorp lavas, emphasize the connection between the two formations. The Black Reef series forms the great escarpment of the eastern Transvaal, where it is thicker than elsewhere, giving rise to some of the finest scenery in the Province. It received its name from the occurrence of black carbonaceous matter in the conglomerates mined for their gold content in the southern Transvaal. In the west of the Union these beds are very probably represented by the Nieuwerust series, which underlies the Malmesbury beds in Namaqualand and Van Rhynsdorp, and by the Kuibis beds in South West Africa. The Black Reef series is conformably overlain by the dolomite in the Transvaal, the neighbouring part of the Cape Province (Campbell Rand series) and in South West Africa (Schwarzalk and Otavi series). In little Namaqualand thick dolomitic limestones lie on the Nieuwerust beds, but from here there is a change which becomes more marked southwards, where

the beds are argillaceous and arenaceous, the Malmesbury beds of the Cape Province. East of the Cape Peninsula, however, in Oudtshoorn and Humansdorp there are again limestones (Cango and Hankey limestones) which may prove to be part of this series. In the Transvaal, Bechuanaland and Griqualand West, the dolomite has a most important influence on the water supply owing to its taking up large volumes in fissures and cavities, and giving the water out again from large springs. It is, in fact, the only formation in the Union which can be said to be water-bearing on a large scale. The rock is compact and usually crystalline, and the water is not held by the rock itself, but is in the widened joints and other spaces. The dolomite is succeeded conformably by the Pretoria series (Griquatown series of the Cape Province), which consists of quartzites, shales, highly ferruginous beds and volcanic rocks, chiefly andesitic (Ongeluk beds). (Plates IX and X.) In the Cape Province and in parts of the Transvaal asbestos, crocidolite and amosite, is strongly developed in the strata below the volcanic horizon, apparently by the re-arrangement of material in the sediments in cross-fibred veins of amphiboles usually parallel to the bedding. Important deposits of iron ore exist in the Pretoria beds in the Transvaal and Griqualand West. (Plate XXVI.) In the Cape Province there is a well developed tillite with striated boulders just below the Ongeluk lavas, and a less well developed tillite has been found in a similar position in the Pretoria district.

On the west coast in the Olifant's River valley of the Van Rhyndorp district and the districts to the south there is an unconformity above the Malmesbury beds, and the younger groups of pre-Cape sediments have thick conglomerates at their base in the Ibiquas and French Hoek beds. Whether the Cango conglomerates include beds overlying the limestones of that area is as yet uncertain, but some thick quartzites and conglomerates of that region apparently underlie the limestones. In the Transvaal the Pretoria series includes three well-marked groups of quartzites, named from below upwards the Timeball Hill, Daspoort and Magaliesberg quartzites.

Formerly the Rooiberg series, consisting of felspathic quartzites, quartzites, shales and felsitic lavas, which were invaded by the Bushveld igneous rocks, and in places clearly form the roof of the Bushveld norite and granite was grouped in the Waterberg system and called "Lower Waterberg." In 1922 it was proved to belong to an older

system than the Upper Waterberg. The Rooiberg series is now provisionally classed with the Transvaal system, but east-north-east of Pilansberg it rests apparently unconformably on lower beds of that system.

BUSHVELD IGNEOUS COMPLEX

A very important feature in the Transvaal is the mass of intrusive rocks which occupies an area some 280 miles long from east to west, and 160 miles wide in the central part of the country, and which is known as the Bushveld igneous complex. (Plate IV.) The rocks are in part covered by fragments of their original roof and partly also by much younger beds belonging to the Karroo system. The mass, as a whole, behaves as a lopolith, with a floor made of the lower members of the Transvaal formation and a roof of the Rooiberg series. It is composed of various rocks, possibly differentiates of a common magma, soda-rich granite, the Red Granite of Transvaal geologists, in the central parts, and more basic rocks, diabase, norite, gabbro, and pyroxenite in the peripheral and lower portions. Intrusions of the granite in the basic rocks prove that the latter solidified first. The mineral and structural changes produced by the Bushveld complex on the surrounding rocks are extensive, and have been made the subject of special studies by A. L. Hall. The numerous sheets of diabase intruded amongst the Transvaal beds in the southern and central Transvaal are regarded as belonging to the Bushveld complex, as are also the long dykes of syenitic rocks in the Transvaal.

The scattered intrusions of nepheline-syenite and related rocks, of which the most important group is that of Pilansberg, are generally believed to be a late product of this great period of igneous activity. S. J. Shand has made detailed studies of these rocks. In Pilansberg, which covers some 200 square miles and is situated in a region of weakness where the WSW synclinal axis of the Bushveld is crossed by an important group of NNW dykes. Shand discerns the following sequence of events; granite magma left at depth after the intrusion of the red granite reacted with the dolomite and gave rise at the weak place to a group of small volcanoes which threw out a cover of tuff and lava; the alkaline magma then made its way along the base of the volcanic rocks and formed a laccolite with a floor of granite and norite and a roof of volcanic beds; the top of the laccolite carrying the volcanic rocks collapsed, and magma welled up around it. The date of these events

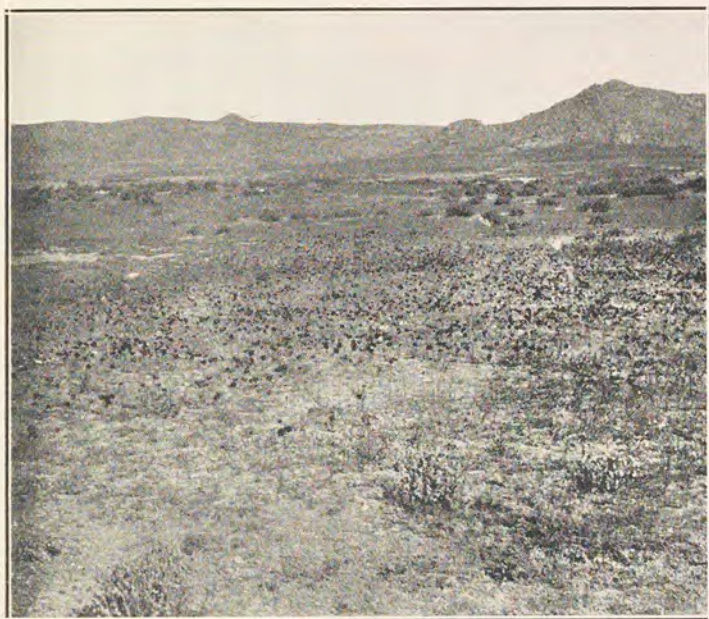


Plate V.—Namaqua Highlands east of O'okiep mine.

[Photo, A. W. Rogers.]

is uncertain. The rocks are of pre-Karoo age, as are the related dykes in Heidelberg, but the date relative to the Waterberg system is unknown, though the absence of recognized remains of Waterberg sediments in and about Pilansberg supports the idea that the Pilansberg rocks are the older, but no fragments of the Pilansberg rocks or of others closely related to them have been found in the Waterberg beds. There is nothing strictly comparable to the Bushveld complex in other parts of the Union.

The large granite masses of the south-west of Cape Province (Cape Peninsula and its neighbourhood, George, Robertson, and Van Rhynsdorp) are normal granites and are post-Malmesbury (Transvaal) and pre-Cape in age.

The tin deposits of the Transvaal are connected with the Bushveld granite, and the less important tin ores of the Cape district with the granite there. The basic rocks of the complex include commercial deposits of chromite, and also platiniferous dunite and norite.

WATERBERG SYSTEM

The Waterberg system forms large tracts of country in the northern Transvaal (Waterberg and Zoutpansberg districts) (Plate XI), and in the Pretoria and Middelburg districts. In the latter it rests unconformably on the Pretoria beds. It consists of conglomerates and quartzitic sandstones; the colour of the sediments is predominantly red or purplish, and the conglomerates are often coarse. The base of the Waterberg system in the Zoutpansberg is made of volcanic rocks of basaltic type.

The Matsap series of Bechuanaland, Griqualand West, and Prieska is regarded as the correlative of the Waterberg system on account of its stratigraphical position and lithological characters. It lies unconformably on beds belonging to the Ventersdorp and Transvaal systems, and is unconformably covered by the Dwyka. It consists of a great thickness of purplish quartzites with conglomerates and shales; but the arenaceous types predominate. In the middle of the series there is, on the eastern side of the Langebergen, a thick volcanic group, andesitic lavas, and tuffs. The Matsap and Waterberg beds have not been connected by mapping between the north end of the Langebergen and the Transvaal through Bechuanaland, but they may well be parts of one system.

CAPE SYSTEM

The Cape system is developed in the south and west of the Cape Province, and it appears again on the south-east coast near Port St. Johns, and continues through the coast belt of Natal. Only the lowest series is found in the east.

One of the great questions of correlation in South Africa is whether the Waterberg system of the Transvaal is a part of the Cape system; but if, as is generally held, the Waterberg and the Matsap are parts of one system, there are great difficulties in regarding the Cape system as being their southern representative. In the south there is a conformable succession from the Cape beds upwards into the Karroo formation; while in the north a great unconformity, which represents a period of mountain building as well as a very long period of denudation, separates the Matsap and Waterberg formations from the Karroo beds.

The lowest members of the Cape system is the Table Mountain series, a group of sandstones and shales, the former predominating, which builds up the mountains of the Cape Peninsula at Cape Town, and the long ranges

flanking the Karroo on the south and west. (Plate XII.) In the south-western region there is a thick band of mud-stone, containing scattered pebbles and boulders of various kinds of rocks, some of which are striated after the fashion of glaciated stones. This tillite lies about a thousand feet below the top of the series. In the Drakenstein and neighbouring ranges east of Cape Town the quartzites immediately below the tillite as well as part of the tillite are folded and truncated in an unusual way; the appearances are believed to be due to ice moving in a south-easterly direction. The sandstones are often quartzitic, and have a characteristic appearance. They are occasionally conglomeratic, but the pebbles are usually scattered or form layers only one pebble thick.

The second series in the system is the Bokkeveld group, consisting of shales and sandstones, in the lower part of which there is a fairly abundant marine fauna closely related to that of the lower and middle Devonian of South and North America, and less closely to the lower Devonian of Europe. Some of the Cape species have also been found in the Sahara. The Bokkeveld beds form the greater part of the cultivated portions of the Ceres district at the bend of the Folded Belt, east by north of Cape Town, and the valleys between the Zwartberg and the south coast, as well as the valleys immediately north of the Zwartberg, in the Gouritz river drainage.

The third and youngest series is the Witteberg group of shales, sandstones, and quartzites, which are well seen on the northern edge of the Folded Belt along the railway between Touws River and Matjesfontein. These beds have yielded few fossils; only badly preserved plants and a fragment of a eurypterid have been found in them.

The Cape system is fully developed along the south coast from near Cape Town to where it is cut off diagonally by the coast near Port Elizabeth. Going north up the west coast it becomes thinner and thinner owing to denudation in pre-Karoo times, and north-west of Calvinia the Karroo beds rest directly on the older Nama rocks or on granite.

KARROO SYSTEM

The Karroo system occupies the whole of the central part of the Cape Province, almost the whole of the Orange Free State, the western side of Natal, and a large area in the south-eastern Transvaal. No evidence has yet been found that marine conditions occurred in this large area

of deposition during Karroo times, but in a part of South West Africa three kinds of marine fossils have been found in the lower beds of the system. In the southern Karroo the Witteberg series passes up conformably into shales, which are taken to be the base of the Karroo system, and which in their turn pass up into a hard boulder-clay or tillite usually without any precise line of division. In the south-western corner of the Karroo area the shales are wanting and there is an unconformity below the tillite. The tillite is now regarded as of glacial origin by almost all geologists, for on no other hypothesis have the peculiarities of the rock been explained. It has a matrix of mudstone or slightly laminated and sandy, often calcareous, hardened clay, containing pebbles and boulders of many varieties of rocks occurring in places to the north of the spots where they are found in the tillite, and many of them are flattened and striated after the fashion of the stones in glacial deposits of regions which are now, or have within recent times been, covered by sheets of ice. In many districts north of the Karroo the tillite rests upon striated surfaces, or characteristically shaped hummocks of rock called *roches moutonnées*, which is very strong evidence of the glacial origin of the formation. The thickness of the tillite varies from a foot, or so, up to 1,400 feet as in the southern Karroo, or it may even be absent altogether, as in parts of the Transvaal. Four centres of distribution of ice have been recognized by A. L. du Toit; South West Africa, Griqualand West, the central Transvaal, and a region lying east of Natal. The movements of the ice were southwards in general. The tillite is followed conformably by shales in the west, south, and east, but in the Transvaal there is a break of unknown but not great extent at the top of the Dwyka series, as the lowest group of Karroo rocks is called.

The Ecca series follows the Dwyka conformably in the Cape Province and Natal. It consists of shales and sandstones, and in Natal and the Transvaal the middle Ecca beds are the main source of coal in the Union, and they also contain oil-shales. In the south of the Cape Province the Ecca beds reach their greatest thickness—over 6,000 feet. (Plates I and XIII.) The series decreases in thickness northwards, and in the Transvaal it is probably only a few hundred feet thick. The Ecca beds contain a flora characterized by the genera *glossopteris* and *gangamopteris*,

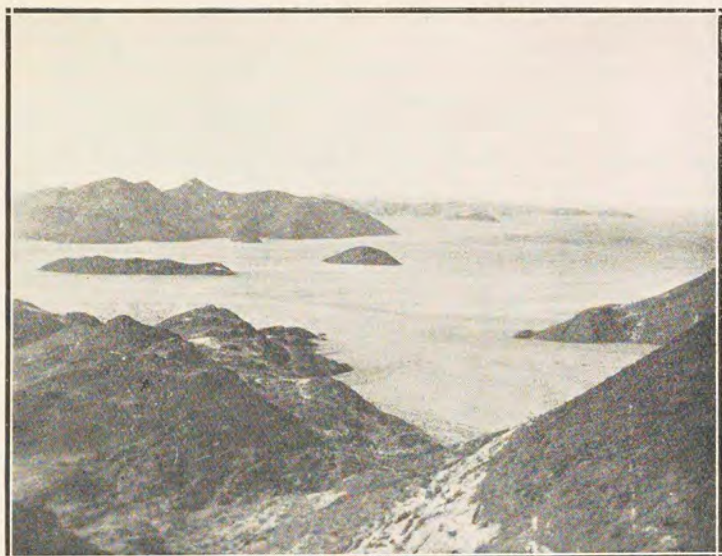


Plate VI.—Sand filled valley of Henkries, Bushmanland. Hills of Old Granite gneiss.
[Photo, A. W. Rogers.]



Plate VII.—Falls 370 feet high on Tsitsa River, south-eastern region. Dolerite sill
overlying Beaufort beds.

[Photo, A. W. Rogers.]

which with their fellows are found also in the Gondwana beds of India, and in Australia, South America, the Falkland Island and in the Antarctic continent.

In five of these regions the *glossopteris* flora occurs in beds overlying tillite like the Dwyka tillite, and it is this fact which leads to the belief that glacial conditions prevailed over a great region in the southern hemisphere at the remote period when the coal-measures of the southern hemisphere were being formed, or soon afterwards. The evidence as to the age of the beds as compared with the European rocks is obtained from Australia and India, for the marine fauna on which it rests does not occur in South Africa.

The Beaufort series lies conformably on the Eccra in the Karroo and south-eastern region (Plates VII and VIII), Natal, and the southern part of the Orange Free State, and it has been definitely recognized in the south-eastern Transvaal. Its most striking feature is the abundance and variety of its reptilian fossils, which are of exceptional interest because they include forms with mammalian relationship and the habit of walking with the body raised clear of the ground as proved by the structure of their legs. With the reptiles are amphibians, fish, lamellibranchiata of freshwater habit, and some plants belonging to the same genera as those in the Eccra below. Sandstones, shales, and mudstones, with a small amount of limestone, chiefly in the form of nodules, make up the Beaufort beds. In the south-eastern Transvaal du Toit has found that the upper coal beds of Volksrust are in the Beaufort series.

The Stormberg series follows the uppermost Beaufort beds conformably in the east of the Cape Province and the neighbouring part of Natal, Basutoland and Orange Free State (Plates II and III), and it is ushered in by the shales and sandstones known as the Molteno beds, which are coal-bearing and include some oil-shales.

The Molteno beds contain a flora with Triassic affinities, but none of the reptiles known from the Beaufort series has been found in them. The Molteno beds occur in the east of the Orange Free State, but they have not been found in the north of that province nor in the Transvaal.

The Molteno beds are succeeded in the Cape, Natal, Basutoland and the south-east of the Orange Free State by the Red beds, which are red weathering sandstones and shales containing dinosaurs and other reptiles and fish.

The Cave sandstone, a rather remarkable formation of thick bedded sandstones, succeeds the Red beds conformably in the Cape, Natal, Basutoland and the Orange Free State, and it also occurs in the Transvaal, where it is known as the Bushveld sandstone. It contains a few dinosaurs, a crocodile, fish, and some small crustacea. The Cave sandstone makes bold outcrops along the slopes of the Drakensberg in East Griqualand, Natal and Basutoland (Plate III.); it is very closely associated with the volcanic rocks of the Drakensberg beds at the top of the Karroo system, which form the precipitous portion of the Drakensberg or Quathlamba range, the Maluti Mountains, and also much of the flat country, Springbok Flats, of the Transvaal Bushveld. The lowest volcanic beds are interbedded with the Cave sandstone, and the series consists of andesitic and basaltic lavas and tuffs. A large number of the vents or necks from which outbursts took place are known, but it is probable that most of the lava came from long fissures now represented by dykes of dolerite. In the Lebombo the basaltic lavas are succeeded by rhyolites. In the Limpopo valley ultrabasic lavas, limburgite and augitite, and nepheline basalt occur at the base of the volcanic group lying on an eroded surface of Karroo sediments and older rocks. The volcanic rocks of Zuurberg are of pre-Uitenhage age, and are underlain by fine grained sandstone containing fragments of bone; they are basalts, tuffs, and breccias, and are probably of Drakensberg age.

To the latest part of the Karroo period belong the intrusions of dolerite, which are found traversing nearly all the rocks in the Union older than the Drakensberg beds, as well as that group. The only large tract in the Cape Province which is free from dykes and sheets of this dolerite is the Folded Belt. The dolerite sheets give rise to the long lines of cliffs capping the escarpment of the Nieuweveld and its continuations to east and west, and both sheets and dykes form conspicuous features in the Orange Free State, Natal, and the Cape Province. In Griqualand East picrites and other ultra-basic differentiates of the basaltic magma have been discovered, and in the Insizwa, Tonti, and Ingli masses they form important bodies of rock which may yield metallic ores of value. The acid differentiates are much more widely distributed. They are small bodies of diorite and granophyre, which rarely give rise to any conspicuous feature.

CRETACEOUS SYSTEM

The Cretaceous system in the Union comprises beds of marine and continental origin found on or near the south and east coasts. The chief areas of these beds are in the Uitenhage and Alexandria districts (where W. G. Atherstone first made out their sequence), Oudtshoorn, Riversdale, and Mossel Bay, where the older beds, called the Uitenhage series, occur. Narrow strips along the coast of Pondoland, and a wider area on the northern coast of Natal, are made of younger Cretaceous beds.

The lowest beds of the Uitenhage series are conglomerates and sandstones, which are followed by plant-bearing shales. In the Sunday's River valley these are succeeded by shales and limestones containing marine fossils of Neocomian age. West of the Uitenhage division marine fossils have only been found in a small outlier of the series near Knysna. All these areas of Uitenhage beds are faulted down against older rocks to the north.

On the south-eastern coast conglomerates and sandstones have been faulted down against older rocks near the Embotyi and Umgazana River; they contain plants and a few marine fossils probably of Neocomian age. The Umzamba series, which lies unconformably on the Table Mountain series near the Natal border, consists of shallow-water, shelly limestones and sands with abundant fossils of Campanian (Upper Senonian) age. In Zululand, north of Tugela River, E. C. N. van Hoepen finds the longest sequence of Cretaceous rocks in South Africa, from Aptian to Upper Senonian.

Near East London and in Alexandria there are some marine limestones of Danian age, but little is known of them yet.

In Bushmanland a remarkable deposit of granite wash containing bones of dinosaurs fills an old valley leading to the Orange River. This may be a remnant of the continental deposits formed when South Africa began to have the type of climate which has led to the formation of the Kalahari, the semi-arid region from which Bushmanland is separated by the valley of the Orange River.

At some time after the Uitenhage beds were laid down, perhaps at a much later date, the peculiar phase of volcanic activity began which is represented by the contents of many pipes and fissures distributed through the central portion of the Union. Some of these carry diamonds and are described in Chapter III. They are found also in the Drakensberg, Riversdale, Robertson, Van Rhynsdorp,



Plate VIII.—Coast Belt. South-east coast line near Kentani outcrops of Beaufort beds. Low level raised beach terrace in distance.

[Photo, A. W. Rogers.]



Plate IX.—Kaap Plateau. The distant hills are composed of lower Griquatown beds and the flat foreground is underlain by the dolomite series.

[Photo, A. W. Rogers.]

Namaqualand, Gordonias and outside the borders of the Union in Rhodesia and South West Africa. Natal seems to be without them. The age of each occurrence can, of course, only be determined by the surrounding rocks, but there are certain features common to them and connecting links between diverse types of material filling the channels, so that it is probable that they were all related in origin. There can be no doubt that some explosive force produced the channels, or took advantage of pre-existing paths of weakness, and that the channels were filled with fragmentary or molten rock derived from various depths between the lower parts of the earth's crust and the superficial strata. As Wagner suggests, the explosions seem to have been connected with the marked rise in level of the sub-continent in late geological times. The most striking instance of a large pipe filled with fragments of the rocks traversed, but apparently devoid of minerals derived from contemporaneous rock magma, is Geitsi Gubib in South West Africa; but similar pipes and fissures exist in Van Rhynsdorp and Ceres. In the Sutherland division there are many vents clustered round Saltpetre Kop filled with material derived from the rocks passed through mixed with minerals belonging to volcanic rocks, and in the neighbouring country there are pipes filled with breccia resembling blue-ground in containing minerals derived from great depths, accompanied by masses of melilite-basalt. Near Robertson a pipe filled with melilite-basalt is situated in the Enon beds of Cretaceous age, and near-by the same formation is penetrated by two pipes containing xenoliths of granulite. The pipes and fissures filled with the rocks commonly known as blue-ground have been more thoroughly explored than any other of these channels, because some of them contain diamond in sufficient amount to repay mining, as at Kimberley, also near Pretoria, and at several places in the Orange Free State. Wagner has shown that these ultra-basic rocks, kimberlites, comprise basaltic and micaceous varieties, both of which may contain diamond, and that this mineral was almost certainly a component of the magma from which they were derived by differentiation at great depths. Xenoliths of eclogite in kimberlites and kimberlite tuffs and breccias have been found with diamond in them, and they have been regarded as the source of the diamond and accidentally associated with kimberlite; but the evidence is now very strongly in favour of these being cognate xenoliths formed at depth in the magma which also gave rise to kimberlite.

The opinion of Carvill Lewis, that kimberlite may have been a melilite-basalt, has not been substantiated, but the occurrence of that rock in several pipes in Sutherland, at Spiegel River, near Robertson, and in Namaqualand, where it also contains nepheline, points to some connection between them (see also Chapter III.).

TERTIARY

Beds of Tertiary age are known in the Union, but little information concerning them is at present available. The best known are those belonging to the Alexandria formation of E. H. L. Schwarz, and there are inshore marine beds occurring at various heights up to some 1,300 feet above sea-level on the south and east coasts. The oldest beds are now farthest from the sea, and the presence in them of *Orthophragmina* indicates their Eocene age. The fossils from the country behind Port Elizabeth are of Miocene age according to Bullen-Newton. On the west coast, in Namaqualand, and to the south there is a series of fossiliferous raised beaches extending to over 100 feet above the sea and containing shells of extinct and living species which indicate the former presence of warmer inshore water than is now found on that coast. (Plate VIII.)

Diamonds occur in some of these raised beaches. None of the early Miocene species described by Böhm and Weisfermel from near Bogenfels, on the west coast, north of the Orange River, have been found in the Union, though the fossil cephalopod, *Aturia*, a genus which occurs at Bogenfels, has been dredged off the Cape Province. Wm. Anderson discovered on the coast of Zululand late Tertiary or early Pleistocene deposits containing the remains of extinct kinds of hippopotamus, buffalo, buck and elephant. Inland deposits of Tertiary age are indicated by the occurrence of mastodon remains in the high-level gravels of the Vaal River near Barkly West. Extinct species of buck and buffalo from the Modder River, and a horse from the south-west coast, are probably Pleistocene.

In the Knysna district on the south coast some valleys in the Table Mountain series are filled in with sands and lignites loosely consolidated; they contain wood and leaves of genera and, in some instances, species still living in the surrounding forest. In certain bays between the Kei and Bashee Rivers on the south-east coast there are lignite-bearing beds with nodules and veins of pyrites; the plant remains in them have not yet been determined. The age of these beds has not been ascertained, but they are probably as old as the Tertiary, if not older.

Gravels far above the level of the modern rivers and the superficial deposits cemented by lime or silica, which are widely spread within the Union, perhaps date back to Tertiary times, but proof of age is lacking. The calcareous tufas are extensively developed in the Kalahari region, the Transvaal, and Griqualand West, and less widely in the Karroo and the coast belt. The recent discovery of the bones of an extinct anthropoid ape in the tufa of the Kaap Rand, near Taungs, points to these deposits being of great antiquity. The siliceous deposits, which are closely connected with those cemented by hydrated iron oxides in the Folded Belt of the Cape, are most conspicuous in the country below the great escarpment, though they have not been noticed in the central part of the Great Karroo. They also occur in the Kalahari, Bechuanaland and Griqualand West.

The gravels which are the site of the diamond diggings in the Transvaal, Griqualand West, and Aliwal North lie at various levels from those of the modern riverbeds (see Chapter III) and many miles from their banks. The deposition of these probably dates back to Tertiary or even late Cretaceous times.

The thick deposits of sand in the Kalahari and Bushmanland (Plates VI and XIV) are of great age, though they are being formed to-day. The evidence from Bushmanland that dinosaurs lived there at the time when the valleys cut in the granite began to be filled with wash from the neighbourhood, and that since then the climate has allowed the steady levelling of the inequalities of the surface, affords an indication that the development of the features characteristic of that region began in pre-Tertiary time.

GEOLOGICAL STRUCTURE

The dominating feature of the structure of South Africa is the great syncline of Karroo beds stretching 820 miles from Karroo Poort in the Ceres division north-eastwards to Carolina in the Transvaal, with a width of 340 miles between Kimberley and the south-eastern coast (see geological map). On the north-western side of this irregularly oval area the base of the Karroo rocks maintains an altitude of between 2,500 and 5,500 feet above the sea, and the beds dip at very low angles towards the basin. On the south, between the Tanqua Karroo and the Keiskama, they are folded in a general east-west direction, and their dip carries them deep under the Karroo region. The shore

Table of Geological Formations

Stratified Formations.		Maximum Thickness.	Igneous Intrusions.	Earth Movements.
Calozoic.	Recent and sub-recent sands, gravels, tufas, ironstones, and surface quartzites; raised beaches	Over 300 feet		Uplift, Depression of coast region, giving rise to lagoons.
	Marine inshore beds of Alexandria, Addo, Bredasdorp, Zululand, and the West Coast; lignites of Knysna	Small		Uplift of whole of South Africa.
Cretaceous System.	Need's Camp series (Danian)	—	Volcanic pipes and fissures of kimberlite and melilitite-nepheline basalts	Uplifts.
	Unzamba series (Senonian); Zululand, Umkwelane Hill; shelly limestones and conglomerates	50 feet		Encroachments of sea on south-east coast.
Mesozoic.	False Bay (Zululand) and Manuan Creek (Cenomanian), Clayey limestones.	50 feet		Faults in region of southern ranges.
	Uitenhage series (Neocomian)	Over 4,000 feet		Encroachments of sea over part of area where southern ranges exist.
Palaeozoic.	Sunday's River beds; marine clays and limestones			
	Wood beds; sands and clays			
Karoo System.	Enon beds; sands, clays, and conglomerates			
	Drakensberg or volcanic beds; basaltic and andesitic lavas and tufts of Quathlamba, Springbok Flats, Lebombo rhyolites and Limpopo limburgites, etc.	4,000 feet	Intrusion of basic rocks throughout the Union	Emergence of land over Karroo region following the restriction of area of deposition during the rise of the southern ranges.
Palaeozoic.	Cave sandstones of Quathlamba and Bushveld sandstones of Transvaal	800 feet		
	Red beds; sandstones and shales	1,600 feet		
Palaeozoic.	Molteno beds; sandstones, shales, and conglomerates with thin coals in Cape Province.	2,000 feet		
	Burghersdorp beds; shales and sandstones	2,000 feet		
Palaeozoic.	Middle Beaufort beds; sandstones and shales	1,000 feet		
	Lower Beaufort beds; shales and sandstones.	7,000 feet		
Palaeozoic.	Ecca series; sales and sandstones; coal in Transvaal and Natal	6,200 feet		
	Dryka series { Upper shales Tillite Lower shales }	800 feet 1,400 feet 1,000 feet		
Palaeozoic.	Witteberg shales and quartzites series	2,500 feet		
	Bokkerveld series; shales and sandstones; marine (Devonian) fossils in lower half	2,500 feet		
Palaeozoic.	Table Mountain series; quartzitic sandstones and shales; tillite in south-western region	5,000 feet		
	In East. Waterberg; sandstones, shales and conglomerates.	5,000 feet		
Palaeozoic.	In West. Matsap series of Griqualand West, etc.; quartzites conglomerates, lavas, and tuffs	Over 7,000 feet		
	Ibiquas beds	2,000 feet	Intrusion of Bushveld Complex	Mountain building in south and west of Cape Province.
Palaeozoic.	Rooberg series; quartzites, shales, and lavas	10,000 feet	Intrusion of younger granites of the Cape Province	Long period of depression and deposition in the south of the Union.
	Campbell Rand Series; dolomites, shales	3,500 feet		Mountain building in Griqualand West, etc.
Palaeozoic.	Black Reef series; quartzites, shales and conglomerates	2,500 feet		
	Pniel series; lavas, tuffs, conglomerates, shales, and quartzites	10,000 feet		
Palaeozoic.	Kuip series; lavas, limestones, chert, sandstones, arkose			
	Zoetliel series; acid lavas, shales, quartzites, conglomerates			
Palaeozoic.	Grootdorm, Numees, Kaigas, and Stinkfontein series			
	Korass series of Kenhardt and Gordonia; lavas, sandstones, conglomerates			
Palaeozoic.	Upper Witwatersrand beds	24,000 feet		
	Main-Bird series; quartzites, grits, conglomerates, shales, and lavas			
Palaeozoic.	Jeppesdorp series, chiefly shales			
	Government reef series; quartzites, shales, ferruginous beds, grits, and thin conglomerates			
Palaeozoic.	Hospital Hill series; quartzites, shales, ferruginous beds, arkose			
	Upper Pongola beds; shales, quartzites, and conglomerates			
Palaeozoic.	Lower Pongola beds; quartzites, phyllites, lavas			
	Abel's Kop beds			
Palaeozoic.	Schists, limestones, banded ironstones			
	Wilgenhout Drift beds; sedimentary and volcanic rocks			
Palaeozoic.	Kaalen beds; quartzites and schists			
	Marydale beds; sedimentary and volcanic beds			
Palaeozoic.	Kraaipan series; schists, ferruginous cherts, and volcanic rocks			
	Moodies series; ferruginous rocks, quartzites, schists, and conglomerates of Barberton and Pietersburg districts			
Palaeozoic.	Schists of sedimentary and volcanic origin in Namaqualand			
		25,000 feet		

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cuts the edge of the syncline from the Gualana to the St. Johns River, and where the base of the system emerges near the latter, it is no longer markedly folded, but, striking through Natal, is affected by faults. The belt of pre-Karoo rocks trending north-north-east through Natal is on the axis of a low, broad anticline much faulted in its eastern limb, which in Swaziland merges in the easterly dipping beds of the Lebombo. Outliers of Karroo beds north of the syncline prove that they once stretched far beyond the borders of the Union, and that over the northern region there has been no earth-movement of the mountain-building kind since the commencement of Karroo times.

The arc-shaped ranges of Griqualand West and Bechuanaland, the Langebergen and Kuruman hills, were undergoing denudation then, and the same statement holds good for much of the Transvaal, where the east-north-easterly trend of the structural lines in the Low Veld of the north, and the east-west syncline of the Witwatersrand are of pre-Transvaal date.

The broad anticline trending east-north-east from the south-west of the Transvaal Province to the west Rand is of pre-Karoo and post-Transvaal age, but it is superimposed upon older and more pronounced disturbances along approximately the same lines. The marked synclinal arrangement about the great Bushveld intrusion, of which the longer axis is directed a little north of east, is a feature of pre-Karoo times. (See geological map and Plate IV.) In the Transvaal the trend-lines of pre-Karoo age are chiefly in an east-north-east direction, and this strike, due to forces acting perpendicularly to that direction, was repeated at long intervals.

In the north and west of the Cape Province the pre-Karoo movements were nearly at right angles to this, and produced north or north-north-west trends, and they were followed by the later movements of the Cederberg region. In the south the east-west trend of the pre-Cape folds was repeated in the late Karroo movements, which give rise to the southern mountain ranges. South and west of the Karroo the ranges with northerly trend in the west, and easterly trend in the south, are made of the Cape formation, and are due to the folding of the crust in late Karroo times by forces which tended to over-fold and thrust the strata towards the Karroo region, and the folds were produced where the Cape and lower Karroo sediments were very thick. (Plates XII, XIII.) The axes of the southern folds

are inclined eastwards, so that the Folded Belt is traversed slantwise by the coast between Cape St. Francis and the Keiskama.

The whole form of the basin, as it is now seen, has been determined by earth movements which gave rise to the dip of the beds, and by denudation removing the folded or nearly flat beds from part of the area formerly covered by them. The thickest deposits of the Karroo system were probably much nearer the southern limit than the northern, but whether the southern limit is within 100 miles of the original limit of deposition is unknown. The outliers in Worcester, Robertson, and Uitenhage prove that the rocks once extended south of the mountain range and there is no trace of an unconformity at the base of the Karroo beds till they reappear on the coast of Pondoland.

The outliers of Cretaceous beds within the Folded Belt, probably remnants of a formerly continuous cover of those beds stretching westwards from Algoa Bay at least as far as Worcester, are faulted down on the south side of fractures parallel to the trend of the pre-existent southern folds. The great Worcester fault, discovered by Schwarz, was for long thought to be of pre-Cretaceous date, but R. H. Rastall has shown that it, like eastern faults of the same group, is of post-Uitenhage age.

The main lines of the structure of Namaqualand were determined in pre-Karoo times; but post-Karoo faulting is proved by the outliers of Dwyka in the valley of the Orange River, not far above sea-level. The flat country of the Kalahari and Bushmanland, now divided by the Orange River, is essentially a pre-Karoo plain, diversified by a few isolated hills, and is being stripped of its cover of Karroo beds except in the large areas where the accumulating sand protects the underlying rocks from denudation.

The great escarpment which plays such an important part in the geography of the Union commences as a definite feature in the slope of the Woodbush, in northern Transvaal, and from there southwards to the Carolina district the base of the Transvaal system forms the uppermost and steepest part; in that district the Karroo beds come in, and higher and higher beds of the system take part in the face of the escarpment as it is followed southwards into Natal, where the Quathlamba is a rampart of volcanic beds at the top of the Karroo formation; in the native territory of the Cape Province the same conditions hold generally,

but the volcanic beds disappear in the Stormberg, and westwards of that region the escarpment is capped by lower and lower beds until in Van Rhynsdorp the Nama system and still older rocks alone take part in its structure. There is thus a broadly symmetrical character in the escarpment on the two sides of the continent, and the asymmetrical feature due to the presence of the volcanic beds in the east has some relation to the submergence of the south-eastern edge of the Karroo basin in the same quarter. Since the escarpment lies, broadly speaking, parallel to the coast, it is natural to look for a connecting link between the two features. The greatest departure from this correspondence is in the south, where the Cape ranges intervene and the coast-line projects in conformity with the curve of the ranges in the Ceres district (syntaxis of the Zwartberg and Cederberg folds), and does not follow closely the blunter sweep of the escarpment. (Fig. I.) In trying to find an explanation of the existence of the escarpment, it is most important to bear in mind the very great age of the interior of South Africa as a land-surface. From the Cape ranges northwards to Central Africa the country has probably been exposed to the air since Triassic times, and for a further period stretching back to Devonian times the sea is not known to have encroached upon it. How far the Devonian sea advanced north of the latitude of Calvinia is unknown. It appears from the present state of our knowledge that the escarpment marks the limit of headward erosion of the rivers draining the coast-belt and the Great Karroo, and that the prominence of the feature for long distances is due to the agents of erosion having encountered resistant horizontal or gently inclined strata or intrusive sheets of dolerite, one or other of which is a prominent feature of the greater part of the margin of the interior plateau. In Namaqualand these flat strata have in part been removed by denudation, but large remnants exist in the Steinkopf plateau, and again in the fragments near Nieuwerust. This view entails the great age of the coast-line as a whole, though it is often held that the straight or smooth shape of the coast indicates recent origin through faulting. The fact, however, that inshore deposits of various dates from early Cretaceous to late Tertiary and recent age are preserved is in harmony with the supposed great age of the coast as a whole, and no great faults parallel to the coast have yet been found. The great faults with down-throw on the ocean side, that flank the southern ranges, are cut

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

by the coast slantwise. The enlargement of the area outside the escarpment in the Cape Province is evidently connected with the folding which took place in the region of the very thick deposits of the Cape and Karroo periods, and that in the north-east part of the Union is connected with the extensive rise in level of the sub-continent in Cretaceous and post-Cretaceous times.

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CHAPTER II

REVIEW OF THE MINERAL INDUSTRY.

In an area that comprises a portion of the north-eastern plateaus of the Union, and stretches into Rhodesia, there flourished in the unknown past a fairly extensive mining and smelting industry. Gold, copper, tin and iron were excavated and the base metals smelted in a large number of localities. The "ancient workings" have naturally aroused much interest. The European prospector of our day found them an excellent guide to deep-seated ore deposits. The ancients apparently could not cope with water and left him everything below the ground-water level. Lately archaeological expeditions have been studying the remains of the ancient miners. Certain investigators have concluded that the work was done by the natives of Africa, perhaps under the supervision of people from other lands, at a time that goes not much farther back than a few hundred years ago. Others have decided that there is evidence of mining activity dating back to several hundreds or even thousands of years before the Christian era. It has been suggested that the mysterious East furnished the mining adventurers who came, won the metals they sought, and departed leaving behind them few clues as to their identity. The finding of a fragment of nickel-bearing bronze, near the ancient smelting sites of Rooiberg, resembling bronzes in Sumerian and other ancient ruins lends colour to the hypothesis of great age.

Whatever the fascinating story of these enterprises may have been it is perhaps fortunate for us that chance, and the lack of technical development of their times, prevented our predecessors from finding and extracting the great mineral deposits that are being mined in South Africa to-day.

The modern history of mining in South Africa is a record of the exploitation of two mineral products, diamonds and gold. Coal was developed in the first place to meet the needs of the diamond and gold mines, and the more recent birth of the iron industry can be attributed to the same cause. The finding and exploitation of all other mineral deposits were greatly aided by the fund of capital and technical skill made available by the two major industries.

To appreciate the influence that the mining of diamonds and gold has had upon the development of South Africa,

it is necessary to go back to the early history of white settlement. When the Dutch colonists landed on the south-western tip of Africa in the seventeenth century they did not find broad fertile plains on which to grow crops, nor navigable rivers to furnish them with highways for the cheap and easy transport of their goods. Facing the narrow coastal strip was a rugged belt of mountains and immediately beyond a semi-arid country which at that time was not considered fit for human habitation. The struggle to establish themselves was a dour one for the colonists from the beginning. A century and a half later, soon after the arrival of the English settlers, the handful of European colonists was confronted with a stream of fierce Bantu immigrants from the north-east, and the history of South Africa in the early part of the nineteenth century is a record of constant fighting on the part of the Europeans to maintain their foothold in the country. By the year 1870 the white settlers had, nevertheless, penetrated to the confines of the present territory of the Union. When diamonds were discovered on the Orange River in 1868, two centuries after the landing of the first colonists, the present area of the Union was occupied by a thinly scattered band of Europeans. Hard times and the blessings of a good climate had moulded these pioneers into an independent, hard-bitten people, but they were sadly lacking in worldly goods. The colony of the Cape of Good Hope is said to have been on the verge of bankruptcy. If one considers that the diamonds found during the next sixty years, within the confines of the Union, were sold for a total sum of about 300 million pounds, the amazing value of this discovery to the inhabitants of the country can be realized. That the world has absorbed the millions of stones unearthed since that time—and used almost entirely for personal adornment—is one of the unexpected phases of this mining episode. The diamond deposits not only provided the country with much needed funds over a long period of years, but brought technical men to the country, and provided a training ground for others in the art of prospecting for and exploiting mineral deposits. Thus, when gold was discovered on the Witwatersrand, there were men on the Kimberley mines willing and able to commence the development of this new enterprise.

In 1886 there was opened up on the Witwatersrand a deposit which, from a comparatively restricted area, has produced within forty-four years gold and other metals to

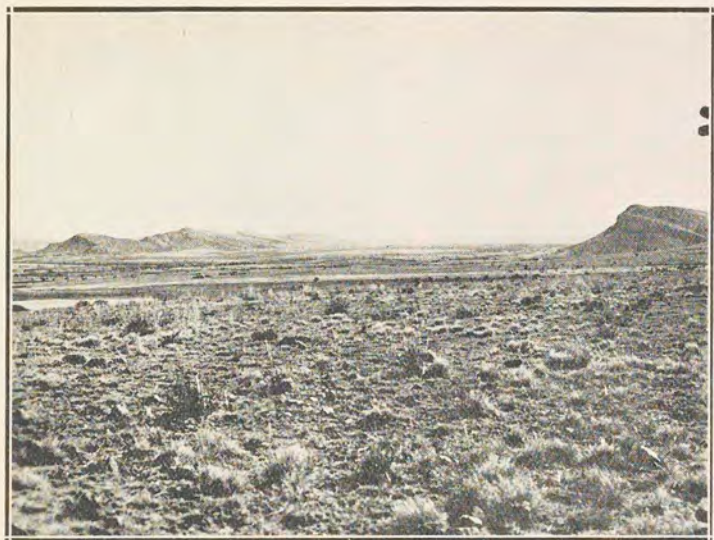


Plate X.—Middleveld west of Pretoria. Pretoria Series: Daspoort quartzite in ridge on left; Magaliesberg quartzite in ridge to right.
[Photo, A. W. Rogers.]



Plate XI.—Limpopo Highlands, Zoutpansberg east of Louis Trichardt showing outcrops of Waterberg beds.
[Photo, Publicity Dept., S.A. Railways.]

the value of nearly 1,000 million pounds. This field has proved of even greater material benefit to South Africa than the diamond deposits and is responsible for two-thirds of the value of the total mineral production of the Union.

Several circumstances have conspired to bring this about. A climate particularly favourable to Europeans; ore-bodies of great magnitude, and large resources of fuel and underground water have made the development of a huge industry possible. Its position far inland has necessitated the construction of railway lines radiating to many points on the coast, and has thus gone far toward solving South Africa's difficult transportation problem. The low grade of its ore-bodies has entailed heavy expenditure of capital on the field over a longer period than is usual in the mining of gold, and this has been directly responsible for the commencement of embryonic industries on the Rand; the comparatively rapid expansion of coal mining; the growth of agriculture throughout the Union; and the investment of capital, derived from the Rand, in prospecting and other mining ventures not only in the Union, but throughout Southern Africa.

The value of so much wealth extracted at this central point in the sub-continent, with accompanying expansion in transportation, agriculture and industry, cannot be over emphasized. Its influence has extended far northward, and the Rand is destined to be a centre of European settlement and of technical training and development which will assist in the future expansion of those sections of Africa where the conditions for European existence are not so favourable.

Of the other minerals that are now being mined, copper was first exploited in Namaqualand in 1852, asbestos in 1893, and there are records of the working of lead and cobalt in the nineteenth century. Most of the other products listed in the table that follows were first opened up after 1905.

The most recent phase of mining in South Africa has been the discovery of very large deposits of the platinum metals in the Bushveld of the Transvaal, and consequent active prospecting of the extensive Bushveld igneous complex, within which occur also chrome, nickel, titaniferous iron ore and tin deposits. Another development of much significance is the realization, following upon the work of Wagner and Wybergh, of the enormous quantities of iron ore and coal that occur in the confines of the Union.



Plate XII.—Robinson's Pass east of Gouritz River in the Folded Belt. Outcrops of Table Mountain sandstones.

[Photo, A. W. Rogers.

VALUE AND QUANTITIES OF MINERALS PRODUCED.

The total value of the mineral products of the Union from the earliest reliable records to the end of 1928, was, according to the official returns, £1,410,909,099 (see table 1). Of this total, in round figures, gold produced 71 per cent., diamonds 20 per cent., coal 5 per cent., copper 2 per cent., and all other minerals 2 per cent. The Rand alone produced 68·8 per cent. of this amount. These figures do not include salt of which a considerable tonnage is produced and which has been exploited since the early days of European settlement, nor of structural materials such as stone and clay products that are becoming increasingly important every year.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

VALUE OF TOTAL OUTPUT OF MINERALS FROM DATE OF EARLIEST EXISTING RECORDS TO DECEMBER 31, 1928.

TABLE No. I.

Mineral.	Transvaal.	Cape.	Orange Free State.	Natal.	Union of South Africa.
	£	£	£	£	£
Diamonds	52,045,151	206,766,739	25,378,747	—	284,190,637
Beryl (Emerald) ...	3,192	—	—	—	3,192
Gold	1,005,578,899	21,947	252	86,514	1,005,687,612*
Osmiridium	579,167	—	—	—	579,167
Platinum	478,603	—	—	—	478,603
Silver	3,631,438	2	1	142	3,631,583
Copper	5,352,593	20,734,721	—	389	26,087,703
Iron ore	5,703	229	—	54,626	60,563
Iron Pyrite	68,678	568	—	—	69,646
Tin	6,261,780	62,482	—	—	6,324,262
Antimony	33,279	—	—	—	33,279
Arsenic	10,648	—	—	—	10,648
Bismuth	300	—	—	—	300
Chrome ore	98,782	—	—	—	98,782
Lead	567,946	7,020	—	—	574,975
Manganese	9,192	179	—	549	9,920
Mercury	5	—	—	—	5
Nickel	38	—	—	—	38
Zinc	50,998	—	—	—	50,998
Tungsten	5,529	£50	—	—	6,149
Vanadium	2,716	—	—	—	2,716
Coal	40,544,397	2,022,043	4,910,835	32,807,897	80,285,172
Natural gas (CO ₂) ...	—	—	—	850	850
Asbestos	1,097,730	1,075,510	—	4,700	2,177,949
Corundum	181,144	1,607	—	10	182,761
Graphite	32,206	—	—	300	32,506
Magnesite	57,172	—	—	—	57,172
Mica	29,893	—	—	—	29,893
Mineral paints ...	1,614	166	—	7,866	9,646
Soda	210,981	—	—	—	210,981
Koslin	—	—	—	144	144
Talc	21,209	—	—	33	21,242
Totals	1,116,960,993	230,694,242	30,289,835	32,964,029	1,410,909,099

* Total value includes gold premium, amounting to £32,740,264, received during period July 24, 1919, to the end of 1924.

Sundry other minerals which are quarried in the Union such as clay, stone, lime, gypsum, fluorspar, flint, kieselguhr, verdite, and fertilizers or salt, are not included in the table, as full information on them is not available.

The following statement shows the output of each mineral for the two years, 1927 and 1928, with such comparative figures as are available for the first half-year of 1929. Statistics of certain of the products are only collected yearly and are not at present completed.

The following statement shows the output of each mineral for the two years 1927 and 1928, with such comparative figures as are available for the first half-year of 1929. Statistics of certain of the products are only collected yearly and are not at present completed:—

Product.	Year 1927.		Year 1928.		Half-Year, Jan.-June, 1929.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Diamonds ¹	4,703,038-329 met. carats	12,392,308	4,372,556-700 met. carats	16,677,772	1,903,126-490 met. carats	5,654,089
Beryl (Emerald) Crystals ..	—	—	—	—	Not complete	Not complete
Gold ²	10,122,490-958 fine oz.	42,997,408	10,354,964-358 fine oz.	43,982,119	5,193,005-015 fine oz.	22,638,480
Platinum	5,653,180 oz.	58,137	5,990-923 oz.	86,921	2,354,173 oz.	38,368
Osmidium ³	10,431,297 oz.	144,191	17,827-638 oz.	21,110	6,532-064 oz.	71,922
Silver ⁴	1,011,735-564 fine oz.	118,531	1,031,376-362 fine oz.	124,094	512,095-651 fine oz.	53,667
Copper	10,806-923 "	577,119	9,968-849 tons	603,552	3,167-960 "	363,732
Iron Ore	85,455-000 "	29,686	23,039-000 "	7,486	42,186-000 "	13,441
Pyrite	2,484-777 "	3,091	4,137-878 "	6,087	2,261-164 "	3,572
Tin	1,928-450 "	329,947	1,989-229 "	269,285	975-912 "	123,728
Arsenic	87-870 "	1,336	35-229 "	548	50-829 "	304
Chrome Ore ⁵	16,982-987 "	24,339	31,327-010 "	35,265	30,983-466 "	44,908
Lead	452-252 "	7,543	42-320 "	571	Nil	Nil
Manganese	300-500 "	345	—	—	Nil	Nil
Natural Gas (CO ₂)	—	—	—	—	—	—
Coal ⁶	13,302,780-000 tons	3,825,664	13,463,415-000 tons	3,672,966	6,855,515-000 tons	1,873,919
Coal By-products—						
Coke	105,800-000 "	120,569	89,418-000 "	97,937	52,669-000 "	55,807
Tar	434,375-000 gallons	19,998	537,235-000 gallons	24,258	244,024-000 gallons	10,572
Sulphate of Ammonia	925-000 tons	10,335	1,032-000 tons	11,064	366-000 tons	3,543
Other	—	8,287	—	9,804	—	4,184
Asbestos	22,140-407 "	343,301	21,054-108 "	399,550	18,081-136 "	270,301
Corundum	1,063-600 "	8,473	2,010-250 "	12,696	869-000 "	5,310
Feldspar	32-000 tons	42	33-000 tons	44	Not complete	Not complete
Fertilizers	2,281-000 tons	2,045	3,148-000 tons	2,213	"	"
Fluorspar	8,358-000 tons	16,536	6,153-000 tons	12,086	"	"
Graphite	64-294 "	2,027	55-602 "	1,670	30-507 "	862
Gypsum	17,000-000 "	18,478	16,393-000 "	13,252	854-000 "	1,693
Magnesite	1,926-250 "	3,495	1,555-250 "	3,161	1,471-537 "	3,270
Mica	1,603-358 "	3,754	3,768-870 "	8,422	222-000 "	467
Mineral Paints	948-500 "	1,897	382-000 "	857	1,196-000 tons	14,127
Soda	2,893-500 tons	32,710	2,661-500 tons	30,127	Not complete	Not complete
Structural Materials—						
Granite	—	19,310	—	25,716	"	"
Limestone	—	5,097	—	6,012	"	"
Sandstone	—	20,655	—	23,965	"	"
Slate	—	8,606	—	7,727	"	"
Talc	14-000 "	190	—	—	"	"
Straitie or Soapstone	321-250 "	2,740	596-356 "	3,993	289-573 "	1,423
Totals	—	61,158,470	—	66,406,372	—	—

For footnotes see next page.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

FOOTNOTES TO TABLE II.

1. Diamonds, value estimated at mine.
2. Gold value estimated at £4-24773 per fine ounce.
3. Osmiridium recovered by gold mines and smelting works on the Witwatersrand and at Heidelberg.
4. Silver mostly contained in gold bullion.
5. Value free on board Union ports.
6. Coal value at pit's mouth. Figures include coal used in the manufacture of coal by-products amounting in 1927 to £40,986 and in 1928 to £37,699.

Calculation of values: The values given are not calculated on a common basis, but may be the value at the mine or free on rail, or in the case of shipments free on board Union ports, or the value obtained abroad.

The values given for iron ore, pyrite, arsenic, manganese, coal by-products, natural gas, graphite, gypsum, fertilizers, feldspar, magnesite, mica, mineral paints, soda, structural materials and talc are based on local sales. Tin, lead and asbestos values based partly on local sales, partly shipped.

Values of beryl, platinum, osmiridium, silver, copper, and corundum and fluor spar are based on the prices shipped.

TABLE No. III.

The distribution of the production among the four provinces of the Union was as follows:—

Province.	Year 1927.	Year 1928.	Increase.	Decrease.
Transvaal	52,702,001	51,140,432	—	1,561,569
Cape	5,270,295	12,322,906	7,052,611	—
Orange Free State	1,318,198	1,313,049	—	5,194
Natal	1,867,976	1,629,985	—	237,991
Union of South Africa	61,158,470	66,406,372	5,247,902	—

The figures given in the foregoing tables are not complete because of the fact that certain manufactured products produced from minerals are not included. The table below is taken from the section on "Manufacturing Industries," Official Year Book No. 10, Union of South Africa, 1927-1928. The returns are for year ending June 30, in each case.

VALUE OF MATERIALS AND ARTICLES MANUFACTURED IN THE UNION.

	1925-1926.		1926-1927.	
	Materials Used.	Manufactured Products.	Materials Used.	Manufactured Products.
	£	£	£	£
1. Clay products ...	85,247	1,084,402	89,153	1,162,244
2. Lime works ...	6,207	252,790	9,959	261,183
3. Other stone and sand products ...	—	—	561,899	1,785,294
Total stone, sand and clay products	—	—	661,011	3,208,721
4. Salt Pans and Refineries	—	138,711	—	132,272
				£3,340,993

No. 1 includes brick, tile, earthenware and pottery. Fuel is not included in value of materials used. No. 3 includes building and ornamental stone, slate, glass, products of cement factories, modelling in cement and plaster and sundry industries. No. 4: The tonnage of salt produced in 1925-1926 was 88,754 and 88,643 tons were produced in 1926-1927.

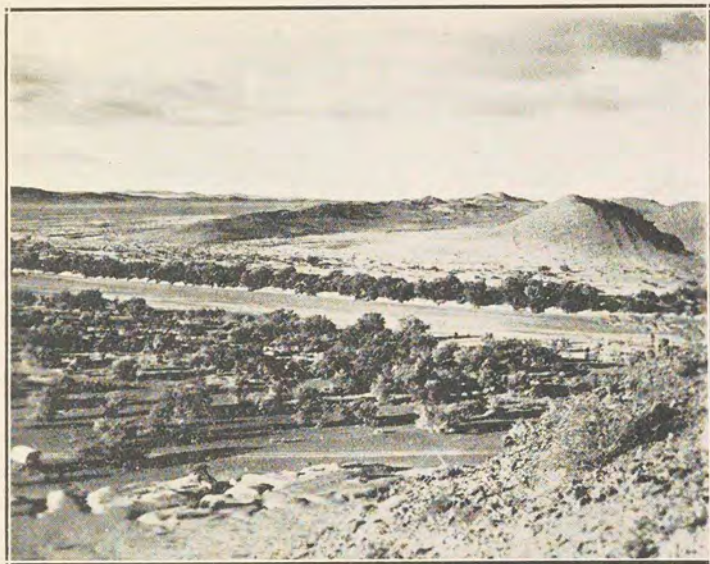


Plate XIII.—The Great Karroo, Prince Albert district. Ridges of Ecca beds near Gamka River on edge of Folded Belt.

[Photo, A. W. Rogers.]

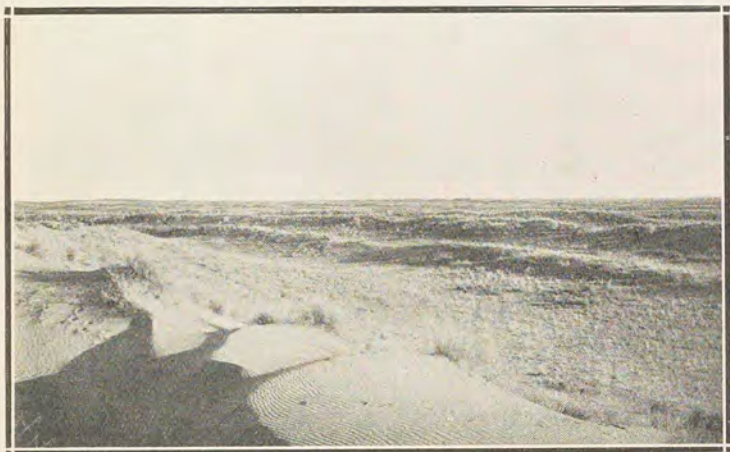


Plate XIV.—Kalahari sand dunes.

[Photo, I. B. Pole Evans.]

The periods over which these returns are taken are not the same as for the main table appearing earlier, so they are not strictly comparable.

However, if from the total value of £3,340,903 we deduct £63,450, which is the value of stone products given in Table II, and add the result to the figures in Table II, it would increase the total value of minerals and mineral products produced in 1928 to £69,683,915. A few other mineral products, such as mica and asbestos are used in the manufacture of goods in the Union, but no figures are available as to the quantity and value of such locally made products.

Of the total of £69,683,915 gold accounted for 63·1 per cent., diamonds 23·9 per cent., coal 5·5 per cent., structural materials, stone and clay products including cement, 4·6 per cent., precious metals, platinum and silver, 0·7 per cent., all base metals 1·3 per cent., and other non-metallic minerals 0·9 per cent. The Rand alone produced 60·65 per cent. of the 1928 production of which 60·35 per cent. was gold.

BASE METALS AND NON-METALLIC MINERALS.*

The output of base metals and non-metallic minerals is relatively very small, and with a few exceptions the consumption in the Union of such minerals and of the products made from them is not met from this output. The chief reason for this is the comparatively undeveloped state of the local manufacturing industry.

Certain metals and minerals are mined and the whole output exported while products made from them are imported. This is true of tin, abrasives and ferro-alloys. In the case of copper, asbestos and mica, most of the output is exported, a small proportion used locally, and other local requirements imported.

Several minerals are produced entirely for the local market, and of these soda, magnesite, talc and sandstone, and limestone for building purposes, are produced in sufficient quantities to supply the local demand. Others are produced for local consumption only, but not in sufficient quantities to satisfy the home market. These are iron ore, pyrites for sulphur, certain stone and clay products, arsenic, lead, coal tar, graphite, gypsum, mineral pigments and salt.

* Information furnished by W. Kupferburger, mineral technologist to the Board of Trade and Industries, Pretoria.

REVIEW OF THE MINERAL INDUSTRY

Finally, there are consumed a number of metals and minerals of which we have at present no local production. These are antimony, aluminium, mercury, zinc, barytes, kaolin, fullers earth, diatomaceous earth (kieselguhr), marble, nitrates, phosphates and petroleum products.

The figures given below refer, in the case of base metals, to the value of metals imported in bar, ingot, sheet and foil form. They include also antimony regulus, zinc spelter, copper and aluminium wire and copper and lead in pipes and tubes. The more important imports of non-metallic minerals and their products are those of crude oil, including asphalt and phosphates and nitrates.

VALUE OF METALS AND NON-METALLIC MINERALS IMPORTED IN 1928

<i>Base Metals</i>			
Arsenic	£17,344	Lead	£21,480
Antimony	4,306	Mercury	13,805
Aluminium	32,818	Tin	145,602
Copper	85,931	Zinc	71,406
Iron and Steel ...	1,897,611	Other Metals	3,343
<i>Non-Metallic Minerals and their Products</i>			
Abrasive products .	£31,542	Mica and mica-nite	£567
Asbestos products ..	47,713	Stone products ...	5,157
Barytes	3,328	Marble	20,274
Cornish Stone and kaolin	1,049	Roofing slate	1,112
Crude oil products	2,555,594	Mineral pigments ...	17,018
Asphalt in bulk ...	89,714	Whiting and chalk	112
Fireclay	1,034	Nitrates	277,382
Fullers earth ...	427	Silica	776
Other earths and clays	3,324	Rock and super phosphates ...	302,157
Graphite	3,497	Sulphur (rock and flowers)	71,243
Gypsum	4,538	Salt	18,470
Kieselguhr	158		

FUTURE PRODUCTION

In considering the future of the mineral industry we are fortunately able to refer not only to the two major products, gold and diamonds, but to include at least three of even greater extent whose potentialities have only lately been realized, that is, platinum, iron and coal. If the value of stone and clay products be disregarded, diamonds and gold together produce about 90 per cent. of the value of South Africa's mineral output and have done so for many years. The Union's output in the immediate future therefore depends on whether the production from these sources can be maintained.

It is believed that the reserves of diamonds in the developed mines of the Union are sufficient to maintain production for nearly a century, and that the output is dependent on the world's market, which is controlled at present by a syndicate. There are large reserves of gold ore on the Rand. The latest estimate of the Government Mining Engineer gives a total of 500 million tons of probable and possible ore, but this is being mined at the rate of 30 million tons per year so there is no indefinite future ahead of the field. There are possibilities, however, of the future extension of the payable mining area into what is now unknown territory, to the south-east and west of the Rand.

Of the platinum metals there are immense reserves in the Bushveld Igneous Complex. The future of platinum mining appears to depend on many factors, among which are the level at which prices can be maintained, and the new uses to which the platinum metals can be put. If prices can be maintained at an average level high enough to permit of the development and profitable exploitation of such mines as are now opened, it is probable that the present metallurgical difficulties will be overcome, and that the assurance of a steady supply will encourage the wide use of these metals. They possess certain exceedingly useful characteristics such as resistance to heat and acids which should find a place for them in the many new phases of applied physical science that are being developed at the present time.

There are very great reserves of iron ore and coal in the Union and chrome and manganese ore in lesser, although also in very large quantities. Of the other deposits, metallic and non-metallic, no reserves comparable to these have so far been discovered.

According to Wagner's estimate there is in the order of 6,000 million tons of "probable" iron ore in the Union, of which 120 million tons is of high grade and the remainder of medium grade. This is exceeded only by the reserves of iron ore in India, the United States, Brazil and France. There is enough manganese and chrome ore to satisfy the needs of a steel industry based on the iron and coal deposits and to permit of exportation as well.

Wybergh's estimate of the coal resources of the Union is on the order of 225,000 million tons, all of which contains a comparatively high percentage of ash and the greater part

of which is of rather low calorific value. The known reserve of coking coals forms a relatively small percentage of the whole.

The actual coal reserves of the Union are undoubtedly sufficient to provide for the needs of the country for many centuries. The coals are of low grade, however, and on that account it is probable that only small proportions of the available reserves will ever be exported as raw material, or even be transported over long distances within the country. The benefit that South Africa will derive from its coal deposits depends therefore upon how much of the poor grade of coal can be turned into products of commercial value at or near the pit's mouth.

With iron and coal deposits of such magnitude the future of the mineral industry in South Africa would seem to lie in their development, and whatever the difficulties in the way of the production and marketing of iron and steel and of coal by-products might be, the present appears to be a better time for investigational work and experimental enterprise along these lines than some future period when our gold mines shall have tapered off in their production.

At present one blast furnace is producing pig iron and another is being contemplated. Coke and other by-products of coal are made in Natal, and tar in the Transvaal. There is every indication that with the local expansion of industry and road building the demand for coke and tar will increase in the near future. The growing consumption of motor spirit and other petroleum products, and the apparent absence of commercial deposits of crude oil in South Africa, would indicate that inquiry into the possibilities of producing motor spirit and related products from South African low-grade coals is a matter of prime national importance. It is therefore apparent that there is urgent need for the establishment of an organization such as the proposed Fuel Research Institute to inquire into these matters.

The development of certain of the non-metallic minerals is influenced by the capacity of local industries to utilize the lower grade portions of their outputs. This is true of such minerals as asbestos and mica. Others must depend wholly upon local industries for their markets. The latest available statistics show an increase of 143 per cent. in the gross value of factory output in the Union over a period of eleven years. One may therefore look for a gradual development of non-metallic mineral deposits in accordance with the expansion of local industry.

Finally there remains the possibility of the discovery of new mineral deposits in the Union. In this connection one of the most promising areas is that underlain by the extensive Bushveld Igneous Complex in the Transvaal, within which are found ore-bodies of platinum, tin and chrome, and which may, from analogy with similar petrographic provinces, be expected to contain nickel and copper in payable quantities. If a mineral deposit is unearthed in this or some other district of the Union, which is larger than, and of different geological character from anything of its kind found elsewhere, and if, in addition, its exploitation profoundly affected the world's consumption of that mineral or metal, the experience would be a perfectly normal one in the history of mining in South Africa.

CHAPTER III

DIAMONDS AND OTHER GEMSTONES

HISTORICAL

EARLY in 1867 a shiny stone picked up by the children of Daniel Jacobs, a Dutch farmer, on the Orange River near Hopetown, excited the curiosity of a neighbour, from whose hands it passed into that of a trader named John O'Reilly. O'Reilly took it to Grahamstown where it was identified as a diamond by Dr. W. G. Atherstone. Later on this stone, which weighed $21\frac{1}{4}$ carats, was sold to the Governor of the Cape for £500. Urged by Dr. Atherstone and others, further searches were made along the Orange and Vaal Rivers, but with indifferent success, until the finding of an $82\frac{1}{2}$ carat gem—The Star of South Africa—two years later. This diamond was purchased from a Griqua herd boy by Schalk van Niekerk (the same man who carried the first diamond found to O'Reilly) for 500 sheep, 10 oxen and a horse. It was eventually sold for £25,000 and gave an impetus to the first mineral "rush" in South Africa, at least since the time of the ancients. In wagons and Cape carts prospective diggers flocked by hundreds from the neighbouring districts and coast towns. Some 50,000 people are said to have visited the fields in 1870. The long trek from the coast was through country that was sparsely occupied by cattle farmers, and in places teemed with great herds of springbok and other game. Meat was of necessity the staple diet and water scarce.

The camps established during the next few years along the Orange and Vaal rivers were the scenes of bustle and excitement such as are always associated with new finds of precious minerals. Because of the fortune that is concentrated in one good crystal, every digger was confronted with the ever present chance of discovering such a fortune in the next scoopful of gravel. There was an equally good chance of his native boy seeing it first and disposing of it for a bottle of brandy to a local trader. With all the elements of riot and sudden death that were present, there was surprisingly little lawlessness or bloodshed on these fields. This was due in part to the aversion that riflemen of the plains have to the carrying of six-shooters, and largely to the fact that many of the settlers brought their womenfolk with them to the diggings.

The search for diamonds was first made along river channels and dry water courses, but in 1870, and the following year, diamonds were found on the surface of

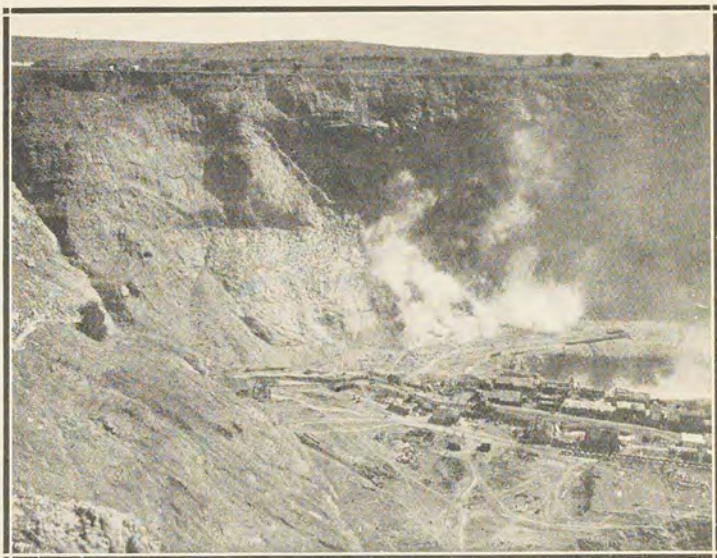


Plate XV.—Blasting at the Premier diamond mine.
[Photo, Publicity Dept., S.A. Railways.]

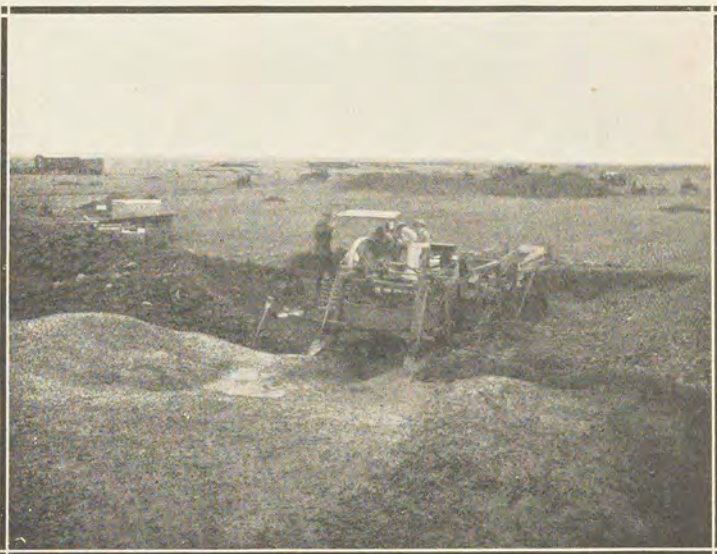


Plate XVI.—View of the alluvial diamond diggings at Bloemhof, Transvaal.
[Photo, Publicity Dept., S.A. Railways.]

volcanic pipes, which later on became the sites of productive mines. The first pipes discovered were Du Toitspan, Bultfontein and Jagersfontein. The De Beers and Kimberley diamond pipes were discovered in the following year, Koffiefontein in 1875 and Wesselton in 1890. The Premier, near Pretoria, was discovered some time before 1902. A group of small but rich mines in the Boshof district, the Roberts Victor, Blaauwbosch and New Eland was proclaimed in 1906, 1910 and 1912 respectively.

The upper portions of the pipes were at first worked by individual diggers, each of whom was entitled to peg a claim 30 x 30 feet. The pipe areas were accordingly pegged off in chequer board fashion, and adjacent portions worked by a multitude of owners independently, and at varying rates. This continued until the difficulties of mining brought about the amalgamation of the different interests into De Beers Consolidated Mines in 1888. Thus started the systematic mining of the great volcanic pipes, from which developed an industry, which with its selling organizations, etc., has kept diamond production on an even keel for forty years.

Searching for alluvial diamonds has nevertheless continued through all this time, and with it has remained the element of romance with which the industry was inaugurated. In 1908 a Cape coloured boy who had worked in the Kimberley mines picked up diamonds in the Namib desert, east of Luderitzbucht, South-West Africa, and this led to the discovery of the unique wind-sorted deposits that occur in that country, in which the richest layers occur on the top rather than at the base of the deposits.

In the Union practically all of the alluvial digging up to the year 1912 was done in the Vaal River basin and along that section of it which lies between the mouth of the Harts river and Bloemhof in the Transvaal. From 1906 to 1912 the production from this source ranged from £400,000 to £500,000 per annum. From 1911 onward stones were being found in increasing numbers farther north than Bloemhof on the plains of the western Transvaal, and in the 15 years 1911 to 1926 £20,000,000 worth of the gems came from there. (Figure 2.)

In 1926 after many years of comparatively small alluvial production, enormous deposits of diamonds were discovered in the northern part of the Lichtenburg district of the western Transvaal. This locality which is close to the mining community of the Rand, was the scene of tremendous excitement in the years 1926 and 1927. In

the earlier part of 1927 the diggings supported a population of 50,000 Europeans and 90,000 natives, and they produced diamonds worth £4,700,000 during that year. About £2,000,000 worth was produced in 1928 and the output has fallen considerably since then. Many of the claims in these diggings were pegged under a system of organized rushes in which literally thousands of citizens engaged in gigantic foot races, under control of the police. The starting line was some miles distant and the finish the area of the supposed diamondiferous ground, choice of claims going to those who got there first. Twenty-five thousand people are said to have engaged in one such rush.

The latest episode was staged in 1927 on the coast of Namaqualand, where after the finding of stones scattered over a long strip of coastline by a number of people, a geologist, by scientific prospecting, in which a fossil oyster shell was used as a marker, discovered an ancient beach line which contained an exceedingly rich deposit of diamonds. These were, moreover, of an average quality that is perhaps finer than any hitherto found in South Africa.

According to official records the total value of diamonds produced in the Union up to the end of 1928, is £284,190,637. The value of the total actually found and sold is estimated to be well over £300,000,000.

Diamonds occur in ancient conglomerates, such as those of the Witwatersrand, in volcanic pipes, and as more recent alluvial deposits. In this chapter each of these deposits and the manner of their exploitation is treated separately, and the economic factors that govern the diamond industry as a whole are discussed at the end.

WITWATERSRAND CONGLOMERATES

Diamonds occur in the conglomerates from which gold is being produced on the Rand and are won along with osmiridium on the corduroy tables. They are present in very minute quantities relative to gold. From most mines no stones have been produced and in other places only one or two have been found. Most of the diamonds have come from Modder B Mine where 194 carats were produced in one year. The diamonds are generally green although one pink stone has been found. The largest stone recorded weighed six carats. The distribution of diamonds over the reef area appears to be related to that of osmiridium, another minute constituent of the reef. Green diamonds

up to 8 carats in weight were found in Witwatersrand conglomerate on the Klerksdorp commonage in the early nineties.

VOLCANIC PIPES

The volcanic pipes, which have been drilled nearly vertically through the rocks of the earth's crust, are filled with foreign inclusions lying in a matrix of an ultrabasic rock called kimberlite. Out of about 150 pipes of kimberlite so far discovered, 25 have been mined and the bulk of the production comes from seven only. In the payable mines the proportion of diamonds existing in the pipes varies from about 1 : 700,000 to 1 : 4,000,000.

DISTRIBUTION

Kimberlite pipes occur in groups over an area embracing 30 degrees of latitude from Sutherland in the Cape Province to Mwanza in Tanganyika Territory $2^{\circ} 30'$ south of the Equator and from longitude E. $16^{\circ} 30'$ to E. $33^{\circ} 30'$. The more important groups are those of Kimberley, Pretoria, Jagersfontein, Koffiefontein and Postmasburg. The producing pipes lie in a fairly well defined belt from Jagersfontein in the Orange Free State to the Premier Mine in the Transvaal, a distance of 350 miles. (Figure 2.)

SIZE AND SHAPE

Pipes vary in surface area from the Premier near Pretoria whose greatest diameter is over half a mile, to those that are less than 100 feet across. (Plate XV.) They are commonly ovoid in plan, although many irregular pipes occur. In vertical section they are for the most part steep sided funnels that are vertical or nearly so. The Kimberley pipe has been worked to a depth of 3,520 feet. The outcrop areas of pipes are not characterized by distinctive topographic features. Their surfaces are usually on a level with the surrounding country, but they may be marked by a slight depression or a protuberance.

GEOLOGICAL FEATURES

Many pipes are compounded of one or more plugs of kimberlite occurring within the same orifice. Each of these may vary slightly in petrological character and the type of diamonds it contains. Underground exploration and mining have proved that these minor pipes may commence at varying depths from the surface. Within the orifice that constitutes the Kimberley mine the westernmost of three pipes passes at about 2,000 feet into

a 3 to 7-foot dyke, the easternmost loses its identity below 845 feet, and the central one persists to the bottom of the mine.

Most of the pipes are connected with narrow dykes of kimberlite which are of an earlier age. This indicates that they are situated on pre-existent lines of fissuring and the supposition is strengthened by the manner in which neighbouring pipes are in many places aligned in plan.

Throughout the wide area over which they occur the kimberlite pipes present the same features and are petrographically practically identical. They are believed to have been extruded from a common magma and during the same geological period.

The pipes pierce rocks of all ages up to and including the lower members of the Karroo system. They include fragments of Stormberg lavas of middle Jurassic age. A plug of melillite basalt which pierces sediments of Neocomian (Lower Cretaceous) age, has by intermediate occurrences been correlated with the kimberlite pipes. They are moreover older than certain Pliocene gravels and are thought to be of Upper Cretaceous age.

Pipe Filling

The pipe filling consists in part of non-volcanic material, but the bulk of it is kimberlite.

The non-volcanic material is composed of material derived from the formations traversed by the pipe, and also of deep-seated ultrabasic rocks called cognate xenoliths, which are not anywhere exposed on the earth's surface. Some of the material is clearly derived from above its present position from strata that were pierced by the pipe, but have since been removed by denudation. In the Wesselton mine near Kimberley, for instance, there are boulders of fossiliferous Beaufort sandstone that must originally have laid 3,000 feet above the Dwyka shales that form the walls of the pipe close to the present surface. Inclusions of this type vary from small pebbles to masses weighing millions of tons. The harder of these boulders are beautifully rounded and polished, while the softer tend to be angular. The deep seated ultrabasic inclusions—cognate xenoliths—are formed of all possible combinations of the minerals olivine, enstatite, diopside, garnet, ilmenite and phlogopite—they form ultrabasic rock varieties known as eclogite, herzolite, hartzburgite and wehrlite. The eclogite nodules composed of augite and diopside have in many cases been found to carry diamonds.

Kimberlite, and material derived from it, constitutes the pipe rock proper. In opening up a pipe it is usual to meet in descending order with:

1. "Yellow Ground" representing completely hydrated and oxidized kimberlite, kimberlite tuff and kimberlite breccia. This extends from the surface to a depth of from 35 to 140 feet.

2. "Blue Ground," the same rocks in a less altered and unoxidized state below the limits of the oxidized zone.

3. "Hardebank" which is the designation applied to relatively well preserved kimberlite that does not disintegrate on exposure to the weather.

"Yellow ground" is best likened to a dried mud or clay of yellow or yellowish-brown colour.

"Blue ground" varies considerably in appearance. As a rule it consists of a serpentinous matrix of slate blue, bluish green or bluish black colour, soft and rather greasy to the touch, through which are scattered, with all manner of foreign inclusions, innumerable serpentine pseudomorphs after olivine, glistening plates of phlogopite, and occasional grains of ilmenite, pyrope, enstatite and chrome diopside. Thin sections proved that some blue ground is merely decomposed kimberlite, other varieties represent altered kimberlite tuff and breccia, and yet others altered injection breccia resulting from the injection of kimberlite into masses of fragmentary material formed by the explosions that drilled the pipes. The inclusions in such injection breccias and those in kimberlite are invariably found to have suffered thermal metamorphism resulting in the development of minerals such as augite, diopside, biotite and garnet.

Petrographically kimberlite may be classed into two main varieties, namely, (a) a mica-poor or basaltic variety allied to melillite basalt, which is especially characteristic of the pipe form of occurrence, but is found also in dykes and sills, and (b) a mica-rich lamprophyric variety allied to alnoite, which in its typical development is found only in dykes, sills and dyke enlargements.

Basaltic kimberlite consists of phenocrysts of olivine, a little phlogopite and ilmenite, and isolated grains of enstatite, pyrope, and diopside embedded in a ground-mass of secondary minerals rich in perowskite, apatite, iron ores and chromite. Less altered varieties have shown that the ground-mass is made up largely of monticellite. Phenocrysts predominate over the ground-mass. The

olivine, which is allied to forsterite, forms over fifty per cent. of the rock and phlogopite three to four per cent. This is a porphyritic monticellite-olivine-peridotite of basaltic habit.

The micaceous kimberlite consists of phenocrysts of olivine and phlogopite in a dark fine textured matrix of phlogopite, olivine, apatite, ilmenite, perowskite and chromite with serpentine and calcite. This is a porphyritic mica-peridotite of lamprophyric habit.

DIAMONDS

Diamonds when present in the pipe matter are found in well formed crystals, broken crystals and cleavage fragments a considerable proportion of the latter being invariably present. The better class of diamond is accompanied by "bort" and impure stones classed as "rubbish." The larger diamonds are usually octahedral in form, the smaller dodecahedral. Cubes are very uncommon. Diamonds with rounded edges are most common, due to growth in the octahedral, and solution in the direction of the dodecahedral and cube faces. Bort is impure or imperfectly crystallized diamond matter. It often occurs in globular or spherical masses with rough surfaces.

Diamonds vary in size from minute stones to the Cullinan diamond of $3,025\frac{3}{4}$ carats, equal to 1.37 lb. avoirdupois. The average size varies from mine to mine. In the more important mines the size varies from 29 per cent. to 65 per cent. over 1 carat in weight (1 carat equals 200 milligrammes).

The colour of the stone varies greatly. White stones tinged with yellow, known as "Capes" and "Silver Capes," are perhaps the most common, the valuable blue whites much less so. All colours are occasionally found. The Premier mine yields stones of many colours. Cutting proves that the colouring matter is for the most part on the outside.

In hardness South African diamonds are slightly inferior to alluvial stones from Brazil and India.

The diamond content of the blue ground of even the richest pipes is exceedingly small, and that of the payable mines ranging from about 5 to 30 carats to the hundred loads,¹ equivalent to from 1/4,000,000 to 1/700,000.

¹ 1 load is equal to 16 cubic feet of broken rock, which weighs approximately 1,600 lb.

There is in general a diminution of diamond content with depth.

Every pipe and every dyke of diamond-bearing kimberlite yields stones characterized by their own peculiarities of crystallization, colour, lustre, surface markings and the like. It has been established, moreover, that in those pipes where there is evidence of the presence of a number of distinct columns of blue ground formed by successive eruptions, each column yields diamonds that are more or less distinguished from the others. Certain kimberlite dykes also carry diamonds, but in the majority of instances the pipes are richer than adjacent kimberlite dykes of antecedent age. Kimberlite dykes that are of later age than the pipes carry no diamonds.

ORIGIN OF THE KIMBERLITE PIPES AND THE DIAMONDS

The pipes are the products of successive eruptions. It has been shown that the blue ground found in different portions of any particular pipe may show marked differences in appearance, properties and diamond content, and the diamonds found in the different varieties of pipe rock may likewise vary considerably in character. It has been proved, moreover, that these differences persist in depth, and appear to be due to variations in the nature of the kimberlite from which the blue ground has been derived. It is thus possible to divide the contents of some of the larger pipes into a number of distinct columns of rock, the contact between which is, in many instances, quite as sharply defined as that between the blue ground and pipe walls. In view of these facts it appears plausible to infer that each of the columns is the product of a distinct outburst, and that most of the larger pipes have been formed by a combination of several other pipes. The Kimberley pipe, for example, appears to have been formed by the coalescence of at least three distinct chimneys, which in all probability owe their origin to a progressive shifting of the centre of eruption along a WNW., ESE., fissure.

The strictly volcanic stage of the eruptions was clearly succeeded in some pipes by a hydrothermal or solfataric stage, during which heated magmatic waters, ascending through the fragmentary material occupying them, gave rise to the formation of minerals such as calcite, zeolites, chrysotile asbestos, mountain cork, pyrite and marcasite. The hydrothermal action also evidently initiated the hydration and serpentinization of the pipe filling, which

has since been carried on without interruption by vadose waters, the pipe matter being profoundly altered to depths far below those to which atmospheric weathering normally proceeds. Thus even the kimberlite from a depth of 3,520 feet in the Kimberley mine is in a more or less advanced state of serpentinization.

A very important consequence of this hydration has been the expansion of the pipe filling, which necessarily took place mainly in an upward direction. It has resulted in many localities in the abrupt upturning of the rocks surrounding pipes at their contact with the yellow ground and in the brecciation and slickensiding of the pipe filling.

As regards the origin of the diamond it is clear from what has been stated above that every eruption of kimberlite gave rise to stones of distinctive character, and this is the best proof that in any particular occurrence the bulk of the diamonds present are normal constituents of kimberlite, and must have crystallized from the magma of that rock probably under intratelluric conditions at great depths.

A certain proportion of the diamonds—probably varying in different mines—is, on the other hand, evidently like many of the larger individuals of olivine, enstatite and pyrope found in kimberlite, of the nature of cognate xenocrysts. Some of them are doubtless attributable to the explosive disruption of bodies of diamond-bearing eclogite belonging to a deep-seated zone of peridotite below the outer acid crust, while others may be original constituents of the particular peridotites from which the kimberlite magma was derived, that escaped solution, and were brought up from below by the magma as inclusions.

METHODS OF MINING

Mining is begun on all the pipes by open-cast work. The rock is broken in benches, the faces ranging from 40 to 100 feet in height. Blasting proceeds on a large scale, deep chambered holes being usually employed and from 5 to 6 tons of ground are broken per pound of dynamite employed. Manual labour is employed for drilling and loading, except that light drills are employed for breaking big lumps resulting from the blasting.

For the removal of the pay ground to the surface the two methods employed are (1) by hauling the ground in tubs running on fixed wires over the edge of the crater, (2) by mechanical truck haulage carried down an incline, either wholly within the mine itself, or cut wholly or partly through the country rock outside.

The depth to which open-casting can proceed depends primarily on the nature of the pipe walls. The depths attained by open-casting in the Kimberley group of pipes were from 400 to 500 feet and at Jagersfontein 780 feet. Because of the size of the pipe exploited and strength of the walls the open-cast at the Premier Mine is expected to attain an even greater depth. (Plate XV.) As depths increase the rock is sent through chutes to drives below the open-cast, and thence to vertical shafts sunk some distance away from the pipe. This is finally superseded by wholly underground methods.

The underground system of mining involves the sinking of two vertical shafts into the country rock at a distance of about 1,000 feet from the pipe. One of these is used for hoisting, the other for ventilation and as an emergency shaft. From one of the vertical shafts main rock haulages are driven to the pipe at vertical intervals of about 600 feet. On the level of these haulages the pipe is developed by means of a rectangular system of main cross drives connected to the haulage. The ground between the main levels is developed by "prospect shafts" one of which is usually in the pipe and the other in the country rock adjacent to it. From these shafts working levels are developed 40 to 60 feet apart in the blue ground by a rectangular system of drives which eventually cuts the ground on each working level into pillars about 20 x 20 feet. Ore passes connect with the main level below.

The method of mining is one of caving and retreating, the general direction of the latter being toward the section of the mine nearest to the main haulage shaft. Starting from the back and then, or at a later stage, from one or both of the sides of the pipe, the object is to leave gradually all of the ground on the level behind either broken or collapsed within a moderately short period, having in the meantime recovered and removed as much as possible of the broken rock. Mining at the same time proceeds in such a way that the ground remaining *in situ* takes the form of a series of great steps descending toward the back and the sides of the mine away from the direction of retreat. A tunnel about 10 to 12 feet wide is first driven along the rim of the pipe, more or less at right angles to the main haulage. From this a raise is put up, and by overhead stoping a series of oblique slices are taken from the hanging so that a longitudinal section of the "chamber" or stope assumes the shape of a right angled triangle, the base of which is the floor of the

tunnel and the hanging the hypoteneuse. The stope is kept filled with broken ground up to a convenient working distance from the hanging wall which is also the working face. Stopping proceeds upward until the apex of the triangle cuts the level above and then side-ways in the direction of the lower part of the stope. When this has proceeded to a sufficient distance a similar stope is started on the level below and a parallel stope on the same level as the first, pillars being left between each pair. The average width of a chamber is about 12 feet, but this depends upon the ground. Where the latter is really good, a width of from 14 to 15 feet is not uncommon; but where it is bad the demands of safety may require it to be brought down to much less than 12, or even abandoned altogether. As the distance between the centres of pillars is fixed, the widening or narrowing of a chamber involves a corresponding change in the size of the pillar separating the chamber being mined, from the worked out chamber behind. Much importance attaches to this so-called "back pillar" which, in view of the considerable pressure to which it is subjected must be carried up with as much straightness and regularity as possible. In practice, it is not often brought below 5 feet in width, but this depends on the nature of the ground, and the height to which the chambers are carried. In order to secure final subsidence in these pillars, within the time required, the plan is sometimes adopted of having the chambers on one level taken up under the pillars of the level above. As the width of a chamber is altered to meet requirements so also may the slope or incline be varied according to circumstances.

The offset tunnels cut in the preliminary blocking of the ground, at centres of from 20 to 22½ feet, serve for loading out the chambers, two out of every three being reserved for this purpose. These are lipped or angled off as far as possible within the chamber to permit of the easy passage of the ground into them. Every third of these tunnels is reserved for entrance to a so-called "poleway," which is simply a rounded recess carried up in the side of the chamber as stopping proceeds, and separated from it by a closed brattice, usually of medium sized round timber, to keep in position the broken ground within. These poleways serve for escape in case of necessity, and at the same time promote ventilation within the chamber.

For the rest the breaking and handling of ground proceed on the lines of progressive and up-to-date mining generally. It is of interest, however, to mention as an example of the scale on which work is conducted, that 86,572 loads, equivalent to 69,257 short tons, have been hoisted at Jagersfontein in a working week of five-and-a-half days.

METHODS OF TREATMENT AND RECOVERY

Following upon the crude expedients of the early days, there was gradually evolved a process of extraction which was universally adopted and adhered to for many years. This process, starting by taking advantage of the natural pulverization that takes place in diamondiferous ground on exposure to the weather, proceeded thereafter by successive stages of wet concentration to the final segregation of the precious stones. The stages of reduction were as follows:—

1. Weathering of the ground by spreading out on prepared floors.
2. Concentration in rotary pans, by which reduction to about 1 per cent. of the original bulk was effected.
3. Treatment of the resulting concentrate, after sizing, by jigs, which effected a further reduction to about one-twelfth of the material received from the pans.
4. Hand sorting of the jig concentrate.

At only one important mine is the process of weathering still entirely relied upon. By other producers, it is either supplemented by the crushing of the harder portion of the ground, or entirely superseded, as at the Premier mine, by stage crushing. The rotary pan still holds the field to a very great extent, but has been largely replaced at the Premier mine by coarse jigging. Hand sorting in all good plants has been superseded by grease tables, except for the highly concentrated material delivered by the latter. As the mines get deeper and the ground harder and less amenable to weathering, the tendency will be to resort more to direct treatment by stage crushing and washing; and, in the same way, but for other reasons, the rotary pan will probably give way to a larger extent to coarse jigging. The pulverization of the ground by weathering involves the preparation of floors extending on a large mine to thousands of acres. The blue ground is spread out on these floors to a depth of 11 or 12 inches and natural processes are assisted, as far as possible, and as circumstances require, by ploughing or harrowing, rolling, and

even watering. The time required for maturing varies much at different mines, but depends largely upon the depth from which the ground has come and the season of the year during which it is exposed. In the most favourable circumstances some mine ground may be ready for washing in as little as four months, but this is exceptional, and the longer it can be allowed to remain out the better. The process results in a more natural freeing of the diamond from the matrix, and has the advantage of assuring large and convenient reserves of ground. On the other hand, it suffers by comparison with direct treatment, in that it involves the locking up for a time of enormous values in diamonds, and a greater liability to loss by theft in consequence of the extra handling of the ground required. The question of comparative cost is still doubtful, and the direct process suffers somewhat from the liability of stones to get broken or splintered in course of crushing, though this appears to have been unduly magnified. It will be obvious that the process of stage crushing, previously alluded to, which involves extraction of the concentrate at successive stages of reduction, has been designed specially to obviate the latter danger.

The rotary pan, which has hitherto played so large a part in recovery processes, is, in its common form, a shallow iron pan with an outer diameter of 14 feet and an inner of 6 feet, leaving an annular space of 4 feet wide, in which the washing or concentration of the ground proceeds. This is effected by the rotation of revolving arms, actuated by a vertical shaft, and carrying wedge-shaped teeth, which sweep round the puddled ground. As the process proceeds, the heavier material is gradually forced towards the outer periphery, where arrangement is made for its extraction, and the lighter material towards the discharge in the inner rim. Much importance is attached to the teeth being adjusted so as to form a regular spiral, and to a certain consistency being maintain in the pulp. Further adjustments of more or less consequence are found in the rate and manner of delivery of the ground to the pan, the height of the discharge, the inclination of the pan bottoms, which rise slightly towards the inner periphery, and the speed of rotation.

Apart from the foregoing, the crushing, sizing, jigging, and other operations are effected by the same machinery and in much the same way as in ore-dressing plants generally, and need no special description. Something must be said, however, of the final recovery of the diamond

by taking advantage of the special affinity which it and certain other gems manifest for grease, in consequence of certain differences between their surface tension and that of the worthless material. This discovery was made by Mr. Fred Kirsten, of the De Beers Company, a good many years ago, but the process to which it led has only gradually come to be universally adopted. It consists essentially of a shaking table, inclined at a suitable angle, and covered with a smooth layer of thick grease, over which sized concentrated material can be carried sufficiently freely by water. In practice the Frue Vanner has been found satisfactory when arrangement has been made for keeping the belt covered with a skin of grease, and for scraping off the material, including the diamonds, retained on it. Care has to be taken that the mixture of grease, mainly a crude petroleum, is suitable, and other adjustments much be attended to, but generally the results are absolutely satisfactory, at least as regards blue ground. It does not give as efficient results in the treatment of yellow ground. The diamonds are easily freed from the adhering grease by melting and treatment with a hot solution of caustic soda.

After recovery on the sorting tables, the diamonds are finally cleaned by being given a bath in hydrofluoric acid, and are then handed over for final sorting, valuation, and shipment. In the course of final sorting a large parcel of stones may be separated, as in the case of the diamonds from the Premier mine, into as many as 1,000 different classes, according to size, colour, purity, shape, and so forth. Diamonds from De Beers mines would on the other hand be divided into about 400 classes only. This work, it need scarcely be said, calls for highly expert training.

COSTS

The cost of mining and treatment varies according to the methods employed and the depths from which the ground is hauled. At De Beers Consolidated Mines Ltd., and New Jagersfontein Mining and Exploration Company, Ltd., where mining is carried on by underground methods at considerable depths, the costs per load washed in 1928 were 4s. 11d. and 3s. 6d. respectively. In the same year the cost at the Premier mine which is worked open-cast and at a shallow depth was 2s. 6d. per load.

LABOUR

The excellent management of labour on these mines has contributed greatly to the low cost of production.



Plate XVII.—The Diggers.

White employees are well paid and treated with much consideration with the result that the mining population has become more settled and contented than is generally the case in large mining areas. For the periods of their contracts which are of limited duration, natives and coloured persons, who work on the mines, are confined to compounds. This system has been attended by the most satisfactory results. From the point of view of the employer it ensures against theft and keeps the labour supply at the highest standard of physical efficiency. The native on the other hand is well fed and cared for and is able to return home at the end of his engagement with his earnings practically untouched.

ALLUVIAL DEPOSITS.

DISTRIBUTION

The principal detrital deposits are those in the valleys of the Vaal and Harts Rivers between Douglas and Klerksdorp, the deposits in the area surrounding Lichtenburg on the high plains of the western Transvaal, and

those on the coast of Namaqualand from the mouth of the Orange River southward. Deposits of lesser importance have been worked east of Kuruman, near Pretoria, and in the Limpopo valley. In South Africa outside of the Union there are also very important deposits along the coast of South West Africa lying from 70 to 324 miles north of the Orange River and within 12 miles of the coast, and others in Southern Rhodesia, the Belgian Congo and Tanganyika.

DEPOSITS OF THE VAAL RIVER BASIN

Wagner has divided these deposits into:—

1. High-level gravels occurring on the plains in the basins of the Vaal and its tributary the Harts River. They lie up to 400 feet above the river channels and as far as 20 miles from them. Examples of these are the gravels between Bloemhof and Schweizer Reneke in the Transvaal. (Plate XVI.)
2. Terraces bordering the present river channels of more recent origin than the High-level gravels.
3. Ancient gravel filled channels, some close to, others at considerable distances from, the present river beds. The Droogeveld channel south of the junction of the Vaal and Harts Rivers is an example of this.
4. Gravels in the present bed of the Vaal River.

Gravel terraces bordering the Vaal River and 70 feet above it at Waldeck's plant carry vertebrate fossils of lower Pleistocene age. The High-level gravels of Schweizer Reneke and Bloemhof are assigned to the Pliocene.

Character of the Gravels

The gravels are of the nature of unstratified river wash consisting of boulders in a sandy or clayey matrix. In this there are found pebbles of chert, quartzite, red jasper, banded ironstone, lydianite, agate, quartz, carnelian, chalcedony and bantams. Bantam from the Dutch "bandom" is a banded pebble of quartz and garnet. Bantams with a specific gravity of 3.3 are generally found with the diamonds in the concentrate. The name is applied also to other heavy associates of the diamonds. With the gravels, ilmenite, pyrope and epidote are also found in places. A red matrix is common in the shallow, but not in the deeper gravels.

The present Vaal-Harts River basins were drained in pre-Karoo times by two ancient valleys, occupying nearly

the same general positions as the present Harts and Vaal systems. The modern rivers occupy parts of the ancient channels and lie in part outside of them. Between the Harts and Vaal valley is a ridge of diabase which is traversed by the Vaal and has, according to Wagner, caused local peneplanation and accumulation of gravel in the valley above the point where the river cuts the ridge. All of the gravels worked for diamonds in this area are apparently river gravels deposited by the post-Karoo, Harts-Vaal-Orange systems. The diamonds themselves have in many cases characteristics which prove that they were derived from some one of the many pipes of kimberlite that occur in the Free State or Griqualand West. Others are unlike any found in pipes so far discovered and their sources are unknown.

LICHTENBURG FIELDS

Alluvial gravels carrying diamonds have a very wide distribution in the northern part of Lichtenburg district. Only part of the area over which they are spread is at present being worked. The existing diggings fall within an ill-defined east-north-eastward trending tract of country twenty-six miles long by eight wide, the centre of which lies sixteen miles north of Lichtenburg village. Within the main area diamonds are found in well-defined "runs" and great irregular patches of gravel. The "runs" are up to 150 yards in width, and some of them can be traced for miles. The patches are clearly remnants of such "runs." The gravels consist of boulders and pebbles of chert embedded in a brown clayey matrix. Angular chert fragments are mixed with well rounded boulders. Quartzite, quartz, agate, and chalcedony are much in evidence. Grains of ilmenite, garnet and other minerals associated with diamonds in kimberlite are rarely found.

The gravels rest on an ancient dolomite surface. For the most part they occupy huge sink holes in the dolomite locally termed "potholes." These are up to 120 feet in depth. The gravels are in places interbedded with thick layers of brownish red clay. The original bedding has been much disturbed, folding and tilting due to subsidence having taken place in most instances. The Lichtenburg diamonds average about one-half carat in weight and are much inferior to those from the Vaal River diggings. Their average value is £2 0s. 0d. per carat as against £7 0s. 0d. for the latter.

Harger concludes that the patches and rivers mark the position of ancient streams flowing from north-east to south-west and that they probably originally formed part of the Molopo River, which drains a part of Bechuanaland and the Kalahari west of the area in question. Solution of the underlying dolomite has caused a slow subsidence of certain sections of the ancient river deposits and has preserved them from denudation.

SOUTH WEST AFRICA.

Alluvial diamonds occur along the coast of South West Africa from 70 to 324 miles north of the Orange River and about twelve miles from the coast. There are three principal areas, Kolmanskuppe east of Luderitz, Pomona, and Bogenfels to the south. The country is characterized by north-south troughs bounded by bare rocky ridges with their floors filled with deposits of gravel and sand.

The diamonds occur for the most part in the upper layer of loose detritus, along the floors of such troughs and in other depressions. This layer is usually only a few inches thick, but may be up to 25 feet thick. It is composed of 20 to 80 per cent. of yellow sand and 20 to 40 per cent. of coarse material from 1 to 10 millimetres in diameter. The diamonds are concentrated with the coarse material which is composed of milky quartz, white feldspar, yellow chalcedony, banded agate, red jasper, red garnet, epidote, magnetite and specular iron.

The immediate concentration of the diamonds is brought about by the action of a wind that blows strongly from the south for many months of the year and takes the fine material out of the upper layers. Previous to this recent concentration some of the diamonds had been deposited as gravels in old river beds of Cretaceous age. Their ultimate source is thought to be pipes of kimberlite. Such pipes occur in this region but up to the present no diamonds have been found in them.

NAMAQUALAND

Alluvial diamonds occur along the coast of Namaqualand from the mouth of the Orange River south-west to Groen River a distance of over 200 miles. The diamonds are found in marine gravels occupying wave-cut terraces lying at elevations of from 20 to 210 feet above sea-level. The greatest distance from the present shore line at which they have been found is three miles. The deposits are for the most part buried by sand, surface limestone and later gravels.

The most important deposit so far found is situated three-quarters of a mile south of Orange River and one and a half miles from the coast. A strip of gravel from 8 to 40 feet wide occupies a storm beach from 110 to 135 feet above sea-level. This has been proved to be very rich in diamonds of exquisite quality. There is an almost complete absence of inferior stones and bort. The first parcel excavated from this locality fetched an average price of over £12 0s. 0d. per carat. The biggest stone so far found weighs 81 carats and one stone weighing 71.5 carats sold for £8,000. Other deposits along this coastal strip have not produced diamonds of as high grade as these.

The diamonds have in part the character of mine stones. They may have been brought down from Griqualand West and the Orange Free State by the Orange River and its tributaries and redistributed by waves and currents or have been derived from submarine pipes off the coast. The first diamonds were discovered in 1926 and by the end of June, 1929, £8,738,149 worth of diamonds had been produced from this area.

Diamonds of similar character have recently been discovered along the coast to the north of the Orange river mouth.

EXPLOITATION

The shallower deposits are worked by stripping the overburden and excavating the gravel. Open-cast methods are used also in working some of the larger potholes in the Lichtenburg fields. On certain of the deep gravel deposits in the Vaal River area however the ground is strong enough to admit of underground work. In such cases shafts up to 100 feet deep are sunk to the payable gravels. Where the diamonds lie along the bottom of an old water-course they can then be excavated by driving along the bottom of the depression. More extensive areas of payable ground are mined by the pillar and stall method.

Deposits in the bed of the Vaal River have been worked by constructing dams or breakwaters above or around the "pools," pumping them dry, and excavating the gravel in the ordinary way. Although such operations are attended with a great deal of risk some of them have yielded handsome profits.

After excavation the gravel is generally sorted, very fine stuff and coarse material being discarded. The intermediate product is then washed in hand operated rotary

pans of the same type as those used on the mines. The concentrate is drawn off at intervals and further concentration effected by hand jigging in small circular sieves with $\frac{1}{8}$ " openings, before being sorted on canvas covered tables.

Certain syndicates, however, work their claims with large and elaborate plants.

At Lichtenburg and other fields far from flowing streams, water has to be hauled to the diggings and its cost is a very serious item of expenditure. White diggers usually employ one or more native helpers.

Life on the diggings is in many respects almost as crude as it was at the time of the first rush to the Orange and Vaal rivers. Periodically some fortunate individual makes a strike that furnishes him with a handsome return, and in rare instances a fortune. This furnishes the incentive that sends many hundreds on a quest which keeps them moving from place to place and from which they manage to gain a bare and rather miserable existence.

ECONOMIC FACTORS

Because the diamond is almost entirely an article of luxury and the mines of South Africa alone produce more than the requirements of the world's markets, it has been found necessary for the principal producers to come to an agreement whereby their joint production is restricted to what the markets can absorb. Periodical agreements have accordingly been entered into between the London Diamond Syndicate and the four chief producers of South Africa, namely, De Beers, South West Africa, Premier and Jagersfontein, whereby the Syndicate buys a certain quantity of diamonds from them at a given price, and the four producers each agree to furnish a certain proportion of the diamonds required. During the year 1928 diamonds valued at £4,574,969 for the Union and £1,216,131 for South West Africa, or a total of £5,791,100 were sold under these agreements.

South Africa is, however, no longer in the happy position it was some years ago of having practically a world monopoly of the supply of diamonds. Production from other parts of the world, notably Angola, Belgian Congo, British Guiana and West Africa has increased until it has now more than one quarter of the total. Flooding of the market from these sources has been prevented by the inclusion of producers in Angola and the Congo among those who have agreed to restrict their output.

DIAMONDS AND OTHER GEMSTONES

A further complication has arisen of late because of the relative increase in the production of alluvial stones, the sales of which are only partly controlled. Four years ago only one quarter of the diamonds sold from the Union were alluvial stones whereas in 1928 the proportion of alluvial stones was 55 per cent.

GOVERNMENT CONTROL

Except in the case of a few farms, precious stones are the property of the State. In the case of a mine, save for various existing concerns, the Government retains the right to one half if existing on private and seven tenths if existing on Crown reserves. The State owns a six tenths interest in the Premier mine.

For a monthly payment of 5s. a digger may peg and work a claim from 1,800 to 2,000 feet square in area, on a proclaimed diggings. Because of the ease with which diamonds can be stolen stringent laws are in existence which make the buying and selling of uncut stones unlawful except to properly licensed persons. All diamonds purchased on the diggings have to be examined by Government experts who are able to distinguish the stones from the various deposits, and such examinations are a check on the sale of stolen diamonds as products of alluvial claims. Formerly the discovery of a payable alluvial deposit invariably led to the proclamation of the ground as a public diggings after the owner's and discoverer's rights had been secured. The over production of the Lichtenburg fields gave rise in 1927 to legislation which enabled the Government to grant or prohibit the prospecting and working of diamonds on private as well as Crown lands, and to control the disposal of the diamonds won. In Namaqualand the Government retains full possession of all diamonds on Crown reserves except over the several discovery rights that have been granted. Outside of these discovery claims the fields are being operated as a State diggings. An export tax of ten per cent. on uncut diamonds has been in force since 1919. There is a further tax of 15 per cent. on profits.

PRICES.

During the years 1911 to 1913 the average prices of mine stones produced in the Union were 32s. 1d., 36s. 5d. and 40s. 1d. respectively per metric carat of 200 milligrams. In 1920 the average price for mine stones had risen to 99s. 9d. At the end of that year, however, a complete collapse occurred in the diamond trade. This

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

was due to over production as well as a world-wide financial depression which caused many of those adversely affected by it to sell their diamond jewellery, and severely curtailed the buying of new diamonds. There has been some improvement in the price since that time.

The prices of alluvial stones, although on the average much higher than those of the mine stones of equal weight, fluctuate on the market in sympathy with the rise and fall of the latter. Price, however, is also dependent upon the quality and size of the diamonds produced. Thus the drop in the average price of alluvial stones during the years 1926 and 1927 as given in the table below is directly due to the large quantity of stones of small size and relatively poor quality sold from the Lichtenburg fields during that period. The sale of stones of good size and quality from the Namaqualand alluvial field in 1928, although in comparatively small quantities, caused a slight advance in average price during that year.

The following figures show the fluctuations in the average prices per carat realized in the past eighteen years for mine and alluvial diamonds:—

Year	Diamonds Sold.		
	Average Price per Metric Carat		
	Mine Stones.	Alluvial Stones.	All Stones.
	s. d.	s. d.	s. d.
1911	32 1	108 3	34 2
1912	36 5	104 11	39 1
1913	40 1	105 11	42 6
1914	37 5	78 1	39 2
1915	45 9	78 3	51 6
1916	39 3	110 3	44 5
1917	44 9	110 11	49 9
1918	48 11	131 0	53 4
1919	85 0	254 9	98 5
1920	99 9	213 3	113 11
1921	64 8	117 8	79 5
1922	46 10	133 4	61 2
1923	51 11	135 9	59 10
1924	52 6	149 7	66 2
1925	57 4	159 5	66 8
1926	58 11	98 7	69 0
1927	58 0	53 6	55 7
1928	45 4	83 7	60 2

DIAMOND CUTTING

By far the greater part of the diamonds produced in South Africa are exported in their natural state to Amster-

dam or Antwerp where they are cut before being put on the market. Two small factories for cutting and polishing diamonds were started in Johannesburg in 1909. Although an export duty of 5 per cent. was imposed on rough diamonds in 1917 it had no perceptible effect on the industry. In 1919 the export tax was raised to 10 per cent. and, in addition, an Act was passed making provision for the establishment, carrying on, regulation and control of a diamond cutting industry in the Union, and for ensuring a supply of rough or uncut diamonds to persons engaged therein. The local cutter thus secures the advantage of the 10 per cent. export duty plus the cost of selling rough stones in Europe, or altogether about 12½ per cent. of the value of the rough diamonds. This Act was amended in 1927 to provide further facilities for local cutters to purchase diamonds and to export small diamonds in a partly manufactured state.

In June, 1929, there were nineteen licensed firms of cutters in the Union and seventeen cutting establishments were in operation, nine at Johannesburg, four at Capetown, three at Kimberley and one at Pretoria. They gave employment to 458 Europeans and 22 coloured persons and during the year ending June 30, 1929, polished diamonds of a weight of 15,295 carats, valued at £521,043.

PRODUCTION

The table below gives the annual output and value of diamonds in each Province from the earliest date for which records are available.

According to official records the value of the diamond output of the Union up to the end of 1928 was £284,190,637. The production of diamonds since the date of their discovery may, however, safely be taken to have amounted in value to over £300,000,000. The Union together with South West Africa produced nearly 73 per cent. of the world's output of diamonds in 1927, and about 63 per cent. in 1928. The official figures are given overleaf:—

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

Year.	Cape of Good Hope.		Transvaal.		Orange Free State		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£	Carats.	£	Carats.	£
1883-1901	53,748,413	69,771,893	†35,509	†69,861	No records available.		Records incomplete.	
1902	2,486,327	4,949,808		1,065		2,402		
1903	2,463,692	4,833,040		174,976		239,752		
1904	2,514,222	5,191,661		884,331		1,150,873		
1905	2,269,450	4,428,383		802,172		922,330		
1906	2,742,868	6,992,811		1,069,392		1,563,141		
1907	2,579,885	6,310,796		2,062,855		2,268,075		
1908	1,588,511	3,085,352		2,022,688		1,549,815		
1909	2,527,297	4,690,478		1,877,486		1,176,680		
1910	2,586,295	5,267,659		2,090,068		1,416,464		
1911	2,250,506	5,506,412		1,843,341		1,628,876		
1912	2,325,549	6,190,966		2,131,406		2,386,979		
1913	2,461,893	6,995,438		2,156,897		2,726,663		
1914	1,350,536	3,514,072		1,142,683		1,162,031		
1915	66,471	266,198		35,674		128,067		
1916	1,510,756	4,057,928		615,209		933,643		
1917	1,650,897	5,109,928		981,525		1,667,299		
1918	1,418,440	4,571,089		896,038		1,717,692		
1919	1,494,855	7,605,053		873,961		2,668,854		
1920	1,364,706	9,463,512		905,297		3,600,310		
1921	238,470	1,305,221		424,486		1,254,151		
1922†	137,471	755,433		415,707		1,192,637		
1923†	1,134,287	3,665,374		680,933		1,736,019		
1924†	1,290,119	4,907,242		851,661		2,161,416		
1925†	1,248,321	5,070,304		902,596		2,214,122		
1926†	1,231,913	5,219,472		1,698,534		4,487,921		
1927†	1,296,248	4,991,818		3,097,831		6,372,046		
1928†	2,134,063	12,019,398		1,915,184		3,647,032		

† 1894-1901.

‡ Metric carat weight.

The following table shows the world production of diamonds for a series of years and indicates the proportion which is contributed by the Union:—

Year.	Union of South Africa.		South West Africa.	Belgian Congo *	Angola.	British Guiana.	Brazil. †	Other Countries.	Total.
	Production	Percentage of World Total.							
	Carats.	%	Carats.	Carats.	Carats.	Carats.	Carats.	Carats.	Carats.
1919 ...	2,588,017	76.36	462,180	211,546	48,504	16,707	59,000	3,337	3,389,291
1920 ...	2,545,017	70.54	606,424	274,103	93,529	39,363	45,000	4,482	3,607,918
1921 ...	806,643	54.29	171,321	244,878	106,719	102,604	50,000	3,619	1,485,784
1922 ...	669,559	47.82	144,156	250,000	57,000	163,641	60,000	15,698	1,400,054
1923 ...	2,053,094	60.74	433,229	414,954	94,478	220,162	164,083§		3,380,000
1924 ...	2,440,398	62.41	492,696	548,274	118,016	190,501	120,115§		3,910,000
1925 ...	2,430,128	56.91	515,860	883,903	125,000	187,745	127,364		4,270,000
1926 ...	3,217,967	56.51	683,801	1,114,384	154,369	168,507	356,768		5,695,796
1927 ...	4,708,038	63.20	723,862*	1,100,000†	170,000†	185,466*	560,000		†7,450,000
1928 ...	4,372,857	56.28	503,142	1,647,700	237,573	135,993	872,735		†7,770,000

* Exports.

† Estimated.

§ The value of exports from Brazil in 1923, amounted to £188,605 and in 1924 to £142,392.

FUTURE OF THE INDUSTRY

It is generally agreed that in the volcanic pipes alone South Africa possesses immense reserves of diamonds that are capable of supplying the world's demand at the present rate of consumption for a great many years to come. The future of the industry in South Africa would seem to depend very largely on whether it will be possible to keep control of the world's market and prevent a drop in price that would force certain of the larger mines to close down.

GEM STONES OTHER THAN DIAMONDS

GARNETS

Garnets of very good quality, and several varieties of spinel occur in the Zoutpansberg district of the Transvaal, but so far these have not been exploited.

VERDITE

A variety of serpentine locally called verdite, has been worked in the Barberton district of the Transvaal. This is an extremely beautiful stone of a green colour, suitable for all manner of small ornaments, clock-cases, etc., but too soft for architectural purposes.

CROCIDOLITE

Certain varieties of the silicified hard yellow material known as "cat's eye" or "tiger eye," an alteration product of crocidolite asbestos, is used for jewellery and for ornamental purposes. The distribution of the valuable species is comparatively limited, little being found away from the farm of Naauwpoort in the Hay District of the Cape Province. Enough is available there, however, to supply the world's requirements for an indefinite time.

JADE

The so-called South Africa "jade" is found in the Transvaal, between Pretoria and Rustenburg. It possesses all the qualities of a semi-precious stone, and has been found well suited for the manufacture of articles of stone jewellery. The commonest colour is green, not much different from that of true jade, but pink and other lighter shades are also found. The mineral occurs under conditions and in quantities which are encouraging.

BERYL

Work was started on opening up a deposit of beryl crystals on the farm Barbara in the Pietersburg district in 1927. Some of the crystals have the quality and colour of true emeralds. Small parcels of these stones

have been cut and valued at prices of from £4 to £5 per carat. In July, 1929, five other companies were carrying on prospecting operations for Beryl in the Leydsdorp District.

REFERENCES.

This chapter is largely based on the publications of P. A. Wagner from which extracts have been freely used. See especially:

1. WAGNER, P. A.: *The diamond fields of Southern Africa*, 347 pages, Johannesburg, 1914, which contains a very extensive bibliography on the subject; also:
2. WAGNER, P. A.: *Geology of South Africa*, in *Handbuch der Regionalen Geologie*, VII Band, 7a Abt, pp. 148 to 156 and 212 to 215, Heidelberg, 1929.
3. WAGNER, P. A., and MERENSKY, H.: *The diamond deposits on the coast of little Namaqualand*. *Trans. Geol. Soc., S. Africa*. Vol. XXXI, Jan. to Dec., 1928, pp. 1 to 42.
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5. DU TOIT, A. L.: *Diamonds in South Africa and Science*, pp. 127 to 147. Hortors, Ltd., Johannesburg, 1929.
6. Extracts have been taken from the portion of the *Year Book of the Union of South Africa* prepared by the staff of the Department of Mines.
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CHAPTER IV

GOLD

HISTORICAL

GOLD was worked in ancient times in the northern portion of South Africa, but apparently not within the area of the Union. The first recorded occurrence of gold was that found near Olifants River in the Transvaal by Carl Mauch in 1868. The Eersteling gold mine, south-east of Pietersburg, is said to have been discovered in 1870. Gold was found in the Murchison range in north-eastern Transvaal in 1870, and alluvial gold near the present village of Sabie, 200 miles east of Johannesburg, two years later. The discoverers were McLachlan, Valentine and Parsons from Natal. This was the beginning of the Pilgrims Rest gold-field, an area which attracted prospectors from the ends of the earth, and where 1,500 white miners are said to have worked alluvial gold in 1875. Flat lying lode deposits were found at Pilgrims Rest soon after its discovery, and the output of the field, which has been in almost continuous operation ever since, has been derived very largely from these ore-bodies. The total yield up to the present is of the value of about fifteen million pounds.

Prospectors drifted from there farther south along the Drakensberg escarpment, and in 1882 alluvial gold was found by a certain Chomse on De Kaap plateau, about forty miles south of Sabie. This was followed soon after by the finding of gold in lode deposits nearby. Graham Barber discovered gold in quartz near the present village of Barberton in 1884, and in 1885 Edwin Bray, then a man of over sixty years, discovered the remarkable lodes of the Sheba mine. The first ore he opened up was enormously rich and caused a rush to the field. By the end of 1886 the population of Barberton had grown to 600 with a floating population of some 5,000 prospectors. The Sheba ore-bodies produced £4,046,876 worth of gold in the next nineteen years, and at one time the shares were quoted at one hundred times their face value. The Barberton field has been kept in practically continuous operation for more than forty years by the enterprise of men such as E. C. Dicey, T. Andrews and others, who have owned and successfully operated small mines in the district. A recent amalgamation of two old properties into the New Consort Gold Mines, Ltd., promises renewed activity in this area.



Plate XVIII.—Resuing on Sub-Nigel mine showing: On the left side a slice taken out of footwall with reel remaining in hanging; in the middle the reel has been taken down; on the right is the waste packed to support the hanging.
[Photo, A. Roberts.]

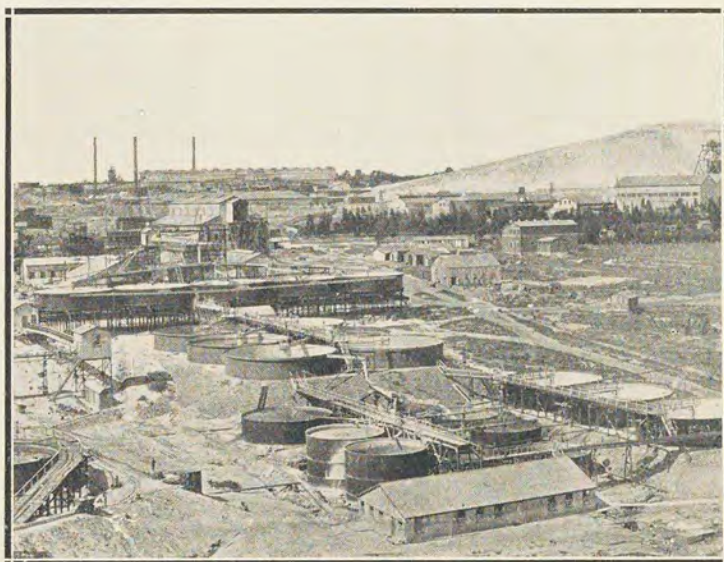


Plate XIX.—Reduction Works, Crown mines.
[Photo, Publicity Dept., S.A. Railways.]

Exclusive of the five years from 1902 to 1906, for which no separate production for Barberton is recorded, the output of gold from the Barberton district from 1885 to the end of 1928 was 1,862,064 fine ounces, valued at £7,909,545. The interest aroused by the discovery of these two fields sent seekers of gold abroad into other parts of South Africa and in that way helped towards finding the larger field to the west.

The Witwatersrand goldfield dates from 1886, and from that time on the history of gold mining in the Union of South Africa is practically that of this area. For although Pilgrims Rest and Barberton have produced steadily up to the present time and small outputs have come from Pietersburg, Klerksdorp and other localities, these places have been entirely dwarfed by the larger field.

Some prospecting was done on the Witwatersrand before the value of the gold-bearing conglomerates that outcropped along the southern side of its long line of ridges was realized. There were rumours of gold finds in this neighbourhood in 1854, and gold is said to have been panned out of rock on the farm Wilgespruit, north of Roodepoort, in 1876.

Some time in 1884 Fred and Harry Struben were invited by a Mr. Geldenhuis the owner of Wilgespruit, a farm north of the present village of Roodepoort, to prospect on his farm. They eventually discovered a quartz vein—the Confidence reef—which in one place yielded 1,000 ounces of gold to the ton, and they erected a stamp battery thereon in December, 1885. Fred Struben is said to have prospected the Witwatersrand conglomerates with poor results in 1885. In 1882-1883 a syndicate consisting of Messrs. R. R. Hollins, C. M. Douthwaite, Alec M. Smith and J. G. Bantjes worked a gold-bearing quartz reef on the farm Kroomdraai 71, a few miles north of Krugersdorp. This was afterwards abandoned. About the end of 1885 Bantjes started prospecting for Douthwaite and himself on the farm Roodepoort, west of Wilgespruit. After failing to find Struben's "Confidence reef" he commenced to prospect the conglomerate bands outcropping north of what is now called the Main Reef.

At the beginning of 1886 both Bantjes and the Strubens did some work on the Bird Reefs, and some of this conglomerate was crushed in Struben's mill with disappointing results. George Walker, a miner who had worked on alluvial gold both at Barberton and Pilgrims Rest, discovered the Main Reef Leader, the principal ore body of

the Rand, in February, 1886, on the farm Langlaagte. It was of high gold content at that point. From the owner he obtained the right to prospect without payment for three months, but at the end of that time was unable to pay the sixty pounds required for a further prospecting term of twelve months and eventually lost his rights. Walker died a poor man in 1924. Bantjes found the Main Reef on Vogelstruisfontein, west of Langlaagte, in February or March, 1886, and had 50 tons of it crushed at Struben's mill. It went about 8 dwt. to the ton. A few months after this Bantjes discovered the Main Reef Leader.

In the meantime Walker's discovery had leaked out and the position of the Leader had been traced to farms on the east side of Langlaagte. A sample of the Main Reef Leader from Bantjes' property was carried to Kimberley in July, 1886, and was the cause of the immediate visit of a number of men from that camp. The late J. B. Robinson, who had made money in Kimberley, came up to the Rand by the next coach. He bought the farm Langlaagte for £7,000 and acquired other rights. He is credited with the sinking of the first shaft on the reef. By this time there was a general rush to the Witwatersrand, and in September, 1886, the new goldfields were proclaimed a Public Diggings. In December lots were sold in the new village of Johannesburg. Three years later there were 25,000 Europeans and 15,000 natives spread over an area which probably did not support 100 in the year 1885.

A telegraph line was opened to the diggings in 1887. During that year and the following coal was discovered near the present villages of Boksburg and Springs, on what is now the Far East Rand. In 1890 a steam railway to carry coal to the gold mines was opened. This railway was unique in that it was built 400 miles from the ocean and had no connection either by water or rail with the sea. A railway connection to the Cape was acquired in 1892 by way of Bloemfontein.

Outside of a serious curtailment of production during the Anglo-Boer War of 1899 to 1902 and other set-backs at the beginning of the Great War and during the strike of 1922, there has been a fairly steady increase in the output of the field from its inception to the present time. The output in 1928 was 9,899,895 fine ounces of gold, 991,812 ounces of silver and 5,936 ounces of osmiridium of a total value of £42,261,617. The total output of gold for the Witwatersrand up to the end of 1928 is 220,263,244

ounces valued at £935,618,789. The total output including silver and osmiridium, a few diamonds and some iron pyrites would be valued at about £940,000,000.

In the meantime the Rand has undergone, or participated in, one raid, one war, and several major riots and strikes. At present the Rand goldfield supports a population of about 580,000 people of whom 272,000 are Europeans. It has produced about £530 worth of gold and its by-products, for every member of the present European population of the whole Union.

Beyond the Rand proper, but from conglomerates belonging to the same geological system, gold has been mined at Nigel village near Heidelberg and near the village of Klerksdorp 103 miles to the south-west. The total production of gold for the Union, including fields outside the Witwatersrand, from the earliest times to the end of 1928 is 229,051,118 fine ounces. The total value of this was £1,005,687,612 including the £32,740,264 received as gold premium during the years 1919 to 1924.

WITWATERSRAND GOLDFIELD.

The Witwatersrand goldfield is situated on the high plateau of the southern Transvaal near latitude $26^{\circ} 15'$ South and between longitudes $27^{\circ} 40'$ and $28^{\circ} 30'$ East of Greenwich. The proven field occupies a strip of country, from two to about seven miles wide, along which a nearly continuous line of mines stretches east and west for fifty miles. At its eastern end, it spreads in wedge shaped fashion to a maximum width of eighteen miles. The city of Johannesburg which lies astride of the central part of the mined area is 394 miles by rail from the nearest port—the town of Lourenço Marques on the east coast of Africa. It is 501 miles from Durban, and 956 miles from Capetown. (Figures 3 and 8.)

The west and central portions of the field lie south of a series of low parallel ridges that are bounded to the north by a line of abrupt escarpments. From these it has derived its name Witwatersrand, the "Ridge of White Waters." The ridge belt is dissected in places by valleys from 200 to 400 feet deep. The picturesque northern suburbs of Johannesburg are built on these ridges and extend to the country beyond the escarpment. In the Central Rand the mines occupy a trough like depression to the south of the high ground with ridges and flat topped hills still farther south and south-west. On the south

side of the western end of the field there is a nearly flat plain. North of the escarpment one overlooks a broken hilly country bounded in the distance by the ridges of the Magaliesbergen.

Eastward the escarpment of the central Rand becomes lower and gradually merges into the High Veld of the Transvaal, a gently rolling country characterized by broad valleys and peculiar depressions known as "pans." Beyond the south-eastern border of the field near Heidelberg village one again encounters parallel ridges or escarpments, but of somewhat more rugged character than the Central Rand and with a south-westerly trend.

Along the Rand to-day the great mine dumps form a chain of white hills that rival the natural ridges in height, and give to the landscape its own peculiar character.

Elevations within the mined areas range from a little over 5,000 to 5,965 feet above sea-level.

The Witwatersrand forms one of the principal watersheds of the southern end of the continent. From its northern slopes the waters drain to the Indian Ocean by way of the Crocodile and Limpopo rivers while southward they are carried by the Vaal and Orange rivers to the Atlantic.

The annual rainfall of this portion of the high plateau is from 25 to 35 inches and most of it falls in the warmer part of the year, October to March. As a consequence of these conditions and of the high altitude the summer climate on the Rand is delightfully cool. At the Union Observatory in Johannesburg the maximum temperature observed during the last twenty years was 94° Fahr. and only on seven days in that period did the thermometer register over 90°. This is lower than the records for New York, London, Paris and Berlin. The winters are dry and sunny. Frosts occur for a few days every winter, and at long intervals there is a fall of snow. Biting cold winds in winter and dust storms in the early spring are the only unpleasant features of an otherwise agreeable and healthy climate.

The natural vegetation is grass, from a few inches to knee high, with a low and sparse tree growth on the slopes of certain ridges. Maize is produced in considerable quantities in the country to the east. The area around the mines has proved to be eminently suited for the cultivation of a varied tree growth and of flowers, vegetables, and most of the fruits of the temperate zones. There are many beautiful gardens on the Rand and there

are probably few mining camps in the world where the conditions of European residence are as pleasant as in the northern suburbs of Johannesburg.

Besides its situation in a healthy district the Rand mining industry possesses two other natural advantages without which it could not have attained to its present proportions. There are large supplies of underground water in the dolomite formations lying near the mines, and an abundant supply of coal within easy hauling distance. These will be referred to again.

THE ORE-BODIES

GEOLOGY

The gold ores of the Rand lie within thin tabular sheets of conglomerates, locally called "reefs." These form part of the Witwatersrand geological system. Certain reefs in the Black Reef series of the Transvaal system also carry gold in places, but they are not important. The Witwatersrand is a conformable system of sediments nearly five miles thick, that lies on an unconformable floor of granite and older metamorphosed rocks. It outcrops for about 170 miles along a narrow strip of country from the village of Springs to near Wolmaransstad in the Transvaal. The Rand goldfield occupies the north-eastern portion of this strip, while small deposits have been worked at Klerksdorp near its south-western end.

The lower half of the system is about 15,000 feet in thickness and is made up of broad zones of shale alternating with fine quartzites, while the upper portion consists, for the most part, of coarse quartzite with many bands of conglomerates. There is a general coarsening of sediments from the bottom upward. Although individual bands of conglomerates are less continuous along the strike, the conglomerate zones increase in thickness and their pebbles are larger, toward the top of the system. The main divisions of the system and their thicknesses as exposed in the central Rand are shown in the accompanying diagram (Figure 4). The Witwatersrand system thins in a south-easterly direction from an area in the Central Rand, so that its thickness near Heidelberg is only 57 per cent. of that in the Central Rand. Individual members vary in different ways, that is the areas in which they are thickest are not the same.

The principal conglomerate zones from the bottom upward, are the Promise, Coronation, Government, Main, Livingston, Bird, Kimberley and Elsburg groups of reef.

Although practically every bed of conglomerate in the system carries some trace of gold, payable ore-bodies have been mined almost entirely from the Main Reef group. Certain bands of the Kimberley reefs have, and are producing, gold towards the western end of the Rand, and isolated bands of the Bird Reef are being mined, but only in one locality.

Payable ore-bodies of small size have been disclosed on the other reef horizons in places, but in most of the places where they have been tested their gold content has been too small to pay for their exploitation.

The Main Reef group, with which we are most concerned, is at the base of the upper division of the system. It is a zone that is from about 20 to about 150 feet wide, within which numerous conglomerate bands occur, interbedded with quartzites and grits. In the central and western part of the mined areas three members are recognised, the Main Reef, the Main Reef Leader and the South Reef. Each of these consists of one or more bands of conglomerate.

The Main Reef, the lowest of the three members, is from about three to twelve feet thick. It is underlain by 600 feet of quartzites and grits between Florida and Witpoortje on the West Rand, and these thin out to the west and east of that locality. The Main Reef and its underlying quartzites finally disappear near Boksburg, and their horizon is taken up farther east by a broad shale zone.

The Main Reef Leader is the principal ore-bearing reef on the Rand. Its thickness varies from a few inches to about ten feet. It is on the whole somewhat "larger pebbled" than the Main and South Reefs. It has been mined nearly continuously from Boksburg west to Vogelstruisfontein, that is for twenty-two or twenty-three miles, and it occurs again beyond the Witpoortje fault in the West Rand. It becomes thinner and more patchy or lens-like from the eastern side of Crown Mines where areas of reef seven to eight feet thick are not uncommon westward, so that it is usually a foot or less in width in the Consolidated Main Reef mine. The principal ore-bearing zone in the Far East Rand, that is east of Benoni, is correlated with this horizon. On the Far East Rand this zone thins gradually, going east and south-east, from its western outcrop in mines like New Modder, and in that direction also the lenses of wider reef gradually spread farther apart in plan. In the western section of New Modder and adjacent

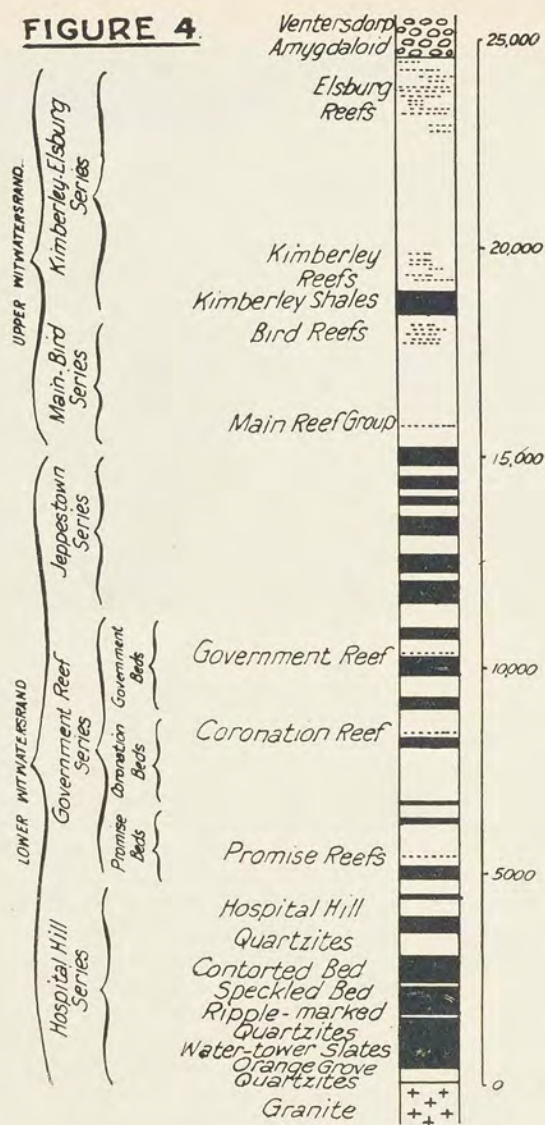


Plate XX.—Rand Refinery melting house. Pouring unrefined gold after melting.
[Photo, A. Roberts.]

mines a number of thin bands of reef occur within forty feet of the main horizon. Several of them have been found to carry payable ore-bodies. They die out to the west and south. Other payable small ore-bodies have been found in this locality in reef bands that occur about 200 and 1,000 feet above the principal reef zone. All these are referred to collectively as the Upper Leaders.

The character of the footwall of the Main Reef Leader varies greatly. Thus the Main Reef and Main Reef Leader are in contact in places in the Central Rand, and in others they are separated by a few feet of quartzite or shaly material. This shale, which is called Black Bar, occurs in patches only. In places, channels have clearly been scoured in the sediments below the Main Reef Leader horizon, but these have been refilled by irregular beds and lenses of Black Bar, quartzites, and conglomerates, before deposition of the Leader. The horizon of the Main Reef Leader maintains a constant, even bedding plane across these filled channels. On the Far East Rand the Main Reef Leader lies upon a shale horizon that is several hundred feet thick. It is an interesting fact that the arrangement of pay areas in the Main Reef Leader does

FIGURE 4.



Section across the Witwatersrand Beds at Central Rand.

After E. T. Mellor.

Explanation

Black—Shale.

Blank—Quartzite.

.....—Conglomerate (reefs).

not seem to be related, in any way, to variations in the structure or composition of its footwall.

The South Reef is from about one to ten feet in width. In the Central Rand area it is separated by from 70 to 110 feet of quartzites from the Main Reef Leader, while in the region of the Simmer and Jack mine and eastward it is in places actually in contact with the Leader. Eastward of Boksburg it has, if present, lost its separate identity. It also occurs on the West Rand. This reef zone is in places divided into a lower thin "leader" band and an upper band that is not distinctive. There is an infinite variety in the amounts of interbedded quartzite, and, within certain limits, of the average size of pebbles, in all of these reef zones.

An interesting phase of the occurrence of gold in the Main Reef group is the bodies of highly pyritic quartzite which occur in the footwall of the Main Reef Leader and also of the Main Reef. In places these are found to carry high gold values.

In the Central Rand the Bird reefs consist of a number of bands of conglomerate lying within a zone of quartzites about 300 feet thick. At the Consolidated Main Reef mine¹ a band of conglomerate from two to seven feet thick is being mined in this zone. From two to six feet above the payable band, and separated from it by bands of quartzite and conglomerate, is a thin dark coloured band of conglomerate with even sized pebbles. This has a characteristic appearance and is used on the mine as a marker. The payable band is from 1,600 to 1,800 feet in section over the Main Reef Leader.

The Kimberley Reefs consist of numerous bands of conglomerate lying within a section of quartzite from 400 to 600 feet in thickness. The reefs are distinguished by somewhat larger pebbles than those in the bands of the Main Reef group and by lesser persistence of the bands along their strike. The base of this pebbly section lies directly upon the broad band of Kimberley shales in the East Rand, but is separated from that band by 300 to 400 feet of quartzite on the Central Rand.

On the West Rand the Kimberley Reef series is comprised of a group of a dozen or more well developed conglomerate beds, situated about 5,000 feet in section above the Main Reef, but, outside of the zone in which

¹ Information contributed by J. Innes, Chief Surveyor Consolidated Main Reef mine.

payable values have been encountered, little is known of these beds for their sub-outcrops lie buried under a covering of Black Reef.

Certain of the reef bands have been mined at the West Rand Consolidated and Randfontein Central mines on the West Rand and a certain amount of mining and development has been done on the Consolidated Main Reef mine. No ore-bodies of any size have been discovered east of the latter. On the Randfontein Estates Gold Mining Company's² property two of the reefs of this series are being worked, and are known locally as the Lindum and Horsham Reefs. The Lindum Reef, which is worked only on this property, carries good values in a fairly definite shoot trending in a south-easterly direction. This reef is about 190 feet in section over the Kimberley shales and from 100 to 150 feet below the Horsham Reef. To the north of the property the Horsham Reef lies above a shale bed, which diminishes and finally disappears as one goes south along the strike of the formations.

The payable reefs of the Kimberley series are characterized by closely packed pebbles of fair size, varying in colour from black to milky white or colourless quartz, pebbles of volcanic origin or of chert are not uncommon.

In this area the reefs are characterized by their high pyritic content. The pyrite occurs disseminated throughout the matrix of the reef as irregular masses, in crystals, or in round nodules called "buckshot." The occurrence of buckshot pyrites is in many places accompanied by an enhanced gold content, more especially is this the case when carbon is associated with it.

Randfontein Central is crushing 50,000 tons per month from the Lindum and Horsham reefs.

The Elsburg Reefs form a numerous group of conglomerates lying within coarse quartzites and grits at the top of the Witwatersrand system. They attain their greatest development in the Central Rand where conspicuously pebbly deposits occur through 1,500 feet of section. Pebbles up to six inches in diameter are common. Individual beds of conglomerate are lens shaped and do not persist for long distances. Small payable ore-bodies have been found in the Elsburg, but no extensive mining has taken place on it.

² Information contributed by K. Richardson, Assistant Consulting Engineer, Johannesburg Consolidated Investment Co., Johannesburg.



Plate XXI.—Portion of Crown Mines, Robinson Deep, etc., from the air.
[Photo, Union of South Africa Air Force.

MINERALOGY.

The ore-bearing reefs are made up principally of pebbles of quartz and quartzite. The matrix is mostly quartz, the grains forming a closely interlocking mosaic. The ore minerals are gold, together with certain platinoid minerals and diamonds, the two latter occurring in very minute quantities relative to gold. The principal gangue mineral is quartz. Pyrite and sericite are present in appreciable quantities through most of the ore. In lesser quantities and approximately in the order of their abundance occur chlorite, chloritoid, rutile, tourmaline, carbon, zircon, calcite, pyrrhotite, galena, sphalerite, chalcopyrite and chromite. Gold is present in exceedingly finely divided form, from 45 to 66 per cent. of the grains ranging from 0.07 to 0.01 millimeters in greatest diameter. The gold grains as examined under the microscope, are rough in outline, with many protruding points, hooks and jagged edges. In places gold occurs in veinlets that pass from the matrix of the conglomerate into the pebbles. It replaces quartz metasomatically. Veinlets of gold pass through individuals of pyrite, and gold is also mechanically intergrown with pyrite. The proportion of gold that is so intergrown, has been proved to form an important percentage of the total gold in the reef. Gold bullion produced from Rand ore contains on an average between 8 and 9 per cent. of silver and about 3 per cent. of base metals, most of which is copper. There is a great variation in the proportion of silver to gold from one part of a particular mine to another.

Certain minerals have been won in minute quantities from concentrates produced in milling. The most important of these is osmiridium, which occurs in proportions varying in different mines of from one oz. in every thousand tons crushed, to 0.1 oz. and less per thousand tons. Other constituents of the concentrates are zircon, diamond, cobalt-arsenide, pyrite, galena, a variety of uraninite, minerals containing the rare earths thorium, cerium, yttrium and others containing traces of aluminium, manganese, phosphorus and vanadium. Many of these minerals are of sedimentary origin, and their distribution along the Rand is of significance in tracing the mode of the origin of the reefs. Quartz is the important gangue mineral, and it occurs as a secondary mineral, as well as being the principal original constituent of the pebbles and matrix of the conglomerate. Secondary quartz is found as a growth upon and between the original quartz

grains and as vein filling traversing the reefs. A small amount of zircon, chromite, and tourmaline occurs as an original constituent of the banket. Much of the tourmaline present is, however, of secondary origin. Pyrite occurs in crystalline form either in cubes or in rounded grains. The average content of pyrite in the Main Reef Leader is estimated at three per cent. by weight, but the proportion is as much as twenty per cent. in places. Pyrite is abundant at many horizons in the Witwatersrand system, but is on the whole more plentiful in the reefs than in the adjacent quartzites.

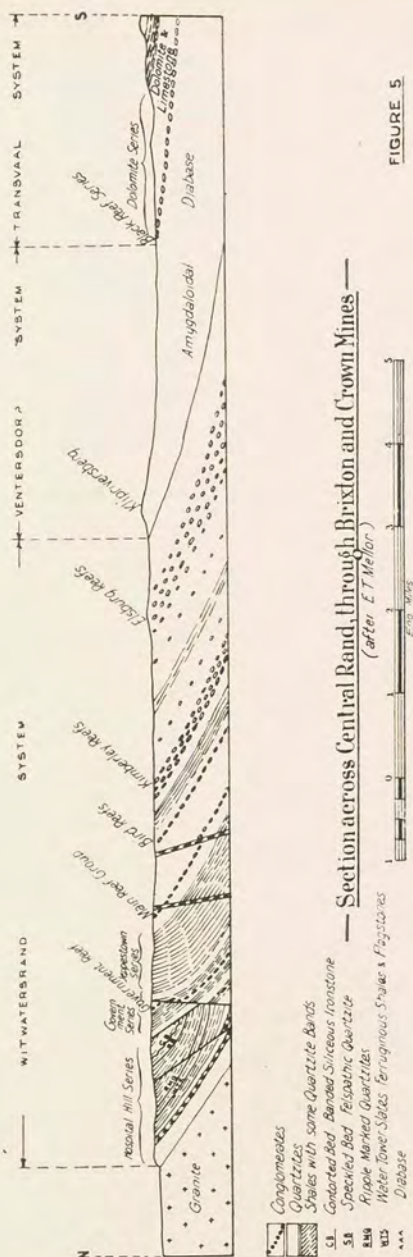
The group of micaceous minerals, sericite, chloritoid and chlorite is the only one of the remaining minerals that occurs abundantly enough in the reefs to be of quantitative importance. Of these three sericite is the most abundant. Lath-shaped crystals of chloritoid are the distinguishing constituents of the metamorphosed shale band known as the Black Bar which lies under the Main Reef Leader in places.

Calcite is abundant in certain localities only; carbon characterizes certain bedding planes, and is found frequently in the payable reef zone on the mines of the Far East Rand. It is particularly well developed also in the payable reef of the Kimberley series on the West Rand.

Microscopic study of the order in which the secondary minerals of the reefs came into place shows that there are at least two, and possibly more, generations of quartz, pyrite, sericite, chlorite, chloritoid and gold. Gold was in places one of the last minerals formed.

STRUCTURE

The structure of the Witwatersrand System is that of a long synclinal fold forty to fifty miles in width, whose axis trends west-south-west. Most of the reefs that are being mined lie on the northern flank of the syncline and dip south. The mined area in the Far East Rand lies at the eastern end of the main syncline, mostly on the northern, but also on the south-eastern flank, and well down towards the trough of the main fold. The reefs that are mined on the north flank of the syncline dip at about sixty degrees and over, near the immediate outcrop, and flatten in depth. (Figure 5.) The average dip in the ground that is mined to-day on the west and central Rand is from thirty to forty degrees. On the east Rand the dips are lower and in some cases the ore-bodies lie nearly flat. Minor synclinal folds whose axes



trend nearly north and south, lie on the north flank of the main fold at the eastern and western ends of the field. Minor anticlinal folds accompanied by faulting are developed on both flanks of the main syncline in the Far East Rand. The axes of the more important ones in Brakpan, West Springs, Springs and Sub Nigel mines trend about thirty degrees west of north. The one on which Sub Nigel mine is situated is seven miles in width.

In the central and western Rand areas extensive faulting has taken place along the strike of the beds. These faults occur for the most part among the alternating zones of shales and quartzites of the Lower Witwatersrand System, but in places they affect the reefs of the Upper division as well. The most important of these, which was first mapped by Mellor, is the Rietfontein fault which eliminates great thicknesses of the Lower series in places. Branching off from it to the south-west are the Witpoortje and Roodepoort faults which have formed a gap in the outcrop of the Main Reef on the West Rand. These and other major faults were formed after the extrusion of the Ventersdorp lavas and before the laying down of the Black Reef Series of the Transvaal System. Similar faults of the reverse type, are found cutting the ore-bodies in the mines. Vertical displacements of up to 300 feet occur along some of them. Horizontal displacement is not easily proven, but an horizontal shift appears to have taken place along at least one such fault in Crown Mines. Many transverse faults are obviously due to the adjustment of blocks of ground between the major east and west faults during and consequent on the movements along the larger faults. Another system of faults is grouped in two sets that trend at about right angles to each other, and their relation to each other would indicate that they are due to the same set of stresses, and therefore of the same age. They are for the most part normal faults. Their trends are about west of north and north of east, the trend varying from mine to mine, and their vertical throw is, in some cases, several hundred feet. They are not related to the major faults and are probably, as a group, of later age. Other faults trending north-south are of still later age. There has undoubtedly been movement along the same fractures more than once in many places. The throw along any given fault plane may vary, giving rise to a wedge of faulted ground along one side of which the displacement increases from zero to several hundred feet, and pivotal faulting in which the down throw side changes

from one side of the fault plane to the other is not uncommon.

The major east-west faults affecting the ore-bodies can be reasonably assigned to the period of formation of the major strike faults to the north, which they resemble, that is, to the time after the extrusion of the Ventersdorp lavas and before the deposition of the Black Reef series. The pressure that acted more or less along the strike of the reefs at the end of the Transvaal Period, and caused the transverse folds in the main syncline, would be apt to form fractures lying at about forty-five degrees on either side of the direction of the pressure, and would account for the two sets of cognate faults lying nearly at right angles to each other. Other but less important faulting succeeded these two periods.

Along the northern flank of this syncline in the Far East Rand faulting is not as intense as in the central Rand area. The close folding that occurs in the Brakpan-Springs line of mines and also in Sub Nigel is accompanied by gravitative block faulting, with vertical displacements of up to 500 feet in places.

Many of the fault planes that cut the ore-bodies are occupied by dykes. These are in most cases of basic composition, but syenitic and more acid dykes are also encountered.

DISTRIBUTION OF GOLD IN THE REEFS

Detailed work has shown that there is a tendency in the Main Reef Leader for gold to be concentrated in pay-streaks that form elongated strips in plan and are of higher value than the ground adjacent to them. Similar pay-streaks occur in the Main and South Reefs. Pay-streaks may be payable areas bordered by ground that is not payable, or they may consist of strips of ground of exceptionally high value bordered by broad payable zones of markedly lesser gold content. There is a variation in gold content also in the vertical section of a reef zone. Within the richer portion of pay-streaks the tendency is for the greatest concentration of gold to occur in a band near the footwall, but such bands also lie in the middle and near the top.

Individual pay-streaks up to 5,000 feet in length and 1,000 in width occur in the east Rand and one up to 1,700 feet in length and 50 to 450 in width in the Central Rand. They tend to line up with their long axes trending roughly in the same direction and such chains of streaks have been traced for over two miles. There is a certain

amount of parallel arrangement between adjacent pay-streaks, but lines drawn along their centres also tend to form a braided pattern in plan. Individuals in a given chain of pay-streaks may be separated by unpayable ground, and not only single pay-streaks, but lines of such streaks come to an end.

It is found that the pebbles of the reefs are on the average larger and of more even size in the richer part of pay-streaks than on their sides. The aggregate reef width, that is the sum of the thicknesses of the various bands of conglomerate that make up a reef zone, is greater along the centre of pay-streaks than along its edges. The pay-streak in fact lies within a lens, or bar, of conglomerate that tends to be coarser and of greater vertical thickness along its central, and more highly auriferous, axis than along its sides, or in the area of low value between pay-streaks. This is very evident in pay-streaks that lie some distance apart, but is true also where they are close together. In such cases the reef zone containing the central rich portion of the pay-streak may not in all cases be wider than the reef zone on the edges, but it is coarser in texture and its actual conglomerate content, as distinguished from interbedded quartzite lenses, is invariably greater. The distribution of these conglomerate lenses in plan within the reef zone corresponds, therefore, to the distribution of the gold in pay-streaks.

An interesting fact is that the average directions of the long axes of the larger pebbles occurring in the centre of such a lens lie roughly parallel to the length of the lens and of the pay-streak.

SECONDARY MINERALS AND GOLD CONTENT

A study of the relation of the quantities of secondary minerals in the reefs and their gold content has shown that although reef that is barely payable is much more frequently intensely altered than barren reef, there is scarcely any difference in the degree of alteration of reef that carries say 15 dwt. of gold and that which carries 55 dwt.

ORIGIN OF THE REEFS

The arrangement of the longer axes of the pebbles parallel to the length of pay-streaks indicates that at the time of their deposition strong currents flowed parallel to the direction of the pay-streaks and the bars of conglomerate lenses that contain them. The same arrangement of the longer axes of pebbles parallel to river currents can be observed in stream beds to-day.

The concentration of coarse material along the central axes of the bars or lenses shows moreover that the stronger line of current swept along over the central part of the bar so that the finer material was "jigged" out and carried away or deposited in quieter water on the sides.

The arrangement in plan of these bars in the reef zones corresponds, therefore, to the arrangement of certain lines of stronger current in the body of water from which they were deposited, and because the pay-streaks occur in the bars, the arrangement of current lines in plan is the same as that described for the pay-streaks, that is, there is a tendency to parallelism and to a braided pattern.

Marine gravels, when laid down on a subsiding land, rising sea-level, are basal conglomerates over-lying a wave-cut bottom of rock or gravel. If deposited on a rising land a thin sheet of poorly sorted gravel is left behind by the retreating sea, interrupted at intervals either by wave-cut steps in the lower formations, or gravel bars parallel to the shore, but coarser in grain on the shore than on the sea side. A conglomerate like the Main Reef Leader evidently does not simulate marine deposits either in its variations in thickness and texture, or its relation to the beds that underlie it. The deposition of the lens-like conglomerate bodies composing this reef on the east Rand in the shape of a fan cannot, moreover, be reconciled with parallelism to a strand line. Their arrangement does, however, resemble that of the current system of a river of large volume and low grade during exceptional inundations, when it breaks away from its channel and spreads in a flood over the surrounding plain. Thus the Mississippi carries pebbles of gravel for 400 miles from their source and deposits them in bars parallel to its course, along those parts of its channel where its current is the strongest. Moreover, when such a stream breaks its banks during times of exceptional floods, the lines of stronger current in the resulting sheet of flood water follow the same braided pattern as is described above.

Mellor ascribed the formation of the reefs to the action of such exceptional river floods over a delta plain.

The gravel of these reefs is, however, much coarser than the rather fine sand laid down in the deltas of present-day rivers. It has been suggested that they were laid down at some distance from the sea, and their coarse character is thought to be partly due to ice action, of which there is evidence in the Lower Witwatersrand. Glaciers could carry coarse material for many miles down

a river plain and deposit them there in the form of moraine or outwash gravels. Flooded waters, such as would accompany a change to warmer conditions, would become heavily loaded with coarse materials and distribute them widely over the river flood-plain, the resulting deposit resembling that of conglomerates like the Main Reef Leader.

In the latest serious contribution to the discussion on the origin of these reefs, Professor Douglas Johnson of Columbia University has suggested³ that conglomerate zones of the nature of the Main Reef Leader simulate a gigantic piedmont alluvial fan deposit, a deposit laid down on a nearly flat plain in front of a mountain range. Such fan deposits are made up of conglomerate lenses which have a braided, and also fan shaped, arrangement in plan with the lenses spreading farther apart toward the periphery. The Main Reef Leader resembles an alluvial fan deposit in the variation of the texture of individual lenses in a lateral direction, that is, in having a band of coarse texture along the centre of the lens with finer material interbedded with gravel along the sides. The texture and arrangement of the bars in the Main Reef Leader do not, according to Johnson, resemble either marine or flood-plain deposits. According to the same authority later studies of glaciation indicate that the waning of an ice age is gradual and that great floods are probably not produced by the change to a warmer climate.

From the way the beds thin to the south-east it is certain that the major movement of the waters and the sediment they carried was from north-west to south-east over at least the eastern part of this field.

ORIGIN OF THE GOLD

The gold occurring in these conglomerates may be conceived to have reached its present position in one of several ways.

1. It may have entered the reef in solution and been deposited there by some precipitating agency such as pyrite or carbon. This can be termed the "Infiltration Hypothesis."
2. It may have entered the reef in the form of solid particles at the time the reefs were deposited, that is as placer gold, and have later on been redissolved, transported for some distance along the reef zone, and re-deposited in the reef. This can be termed the "Redistribution Hypothesis."

³ Communicated by letter.

3. Or it may have been carried in as placer gold and not have been shifted appreciably since that time, the "Placer Hypothesis."

Infiltration Hypothesis

1. There is abundant evidence that much of the gold in the Main Reef Leader has been precipitated from solution subsequent to the formation of the reef. Thus in a few instances veinlets of gold are seen to pass from the matrix of the reef into cracks in quartz pebbles. Gold occurs intergrown with pyrite, and results of mill tests indicate that this operation has taken place on a large scale. Veinlets of gold also traverse grains of pyrite and gold replaces quartz metasomatically. Microscopic study of the Main Reef Leader would, in fact, lead to the conclusion that most of the gold in the reef was precipitated there from solution.

That gold occurs in large pebbled, or rather well sorted reef, as far as pebble sizing is concerned, could be explained by this hypothesis, such reef would, before metamorphism, contain a larger percentage of pore space and larger individual pores, than reef containing a mixture of all sizes with a preponderance of small pebbles. It would, therefore, as in the cases of wide spaces in a fracture, be the more favourable portion of the reef for the precipitation of the gold from solution. This condition would, however, hold only until metamorphism had closed up the pores between pebbles by the deposition of secondary silica and other minerals.

There are indications of the former presence of gold solvents in the reef, and precipitants are present in large amounts. The probabilities are that the precipitants were at all times greatly in excess of the solvents.

There is not much evidence of the solvents manganese dioxide and of chlorides in the reefs, but it is probable that they occur, for dissolved gold has been found in mine waters on the Rand. The principal precipitating agent, pyrite, is present in large amounts in the reef zones. Carbon, another efficient precipitant, is not sufficiently widespread in its occurrence to be a determining factor in the distribution of gold over such a large area as that occupied by the reef ore-bodies.

The preponderance of pyrite strongly suggests that if manganese oxide were present, ferrous sulphate would also be present at depth, but in relatively much greater amounts. Thus any gold that was brought into solution by the small amount of manganese dioxide present would

be re-precipitated by ferrous sulphate before it could be transported for any distance. This is confirmed by the restriction of the gold found in fissures in the immediate neighbourhood of the reef zone.

If the gold in the reefs filtered in solution from the outside it must have had a source and channels to travel in by. Experience in other fields has shown that the source is usually connected with an intrusive batholith of acid or intermediate character. Such a batholith does not outcrop here, but may well be present and not exposed. The dykes that are intruded into the Witwatersrand are mostly basic diabases and dolerites, although some syenite dykes are present. Their position in plan in regard to the pay-streaks does not suggest that they were connected with the source of the metal or that they influenced its distribution.

If gold solutions moved from the outside into the zone of the payable reefs they must have come in through fractures that traverse the sediments and the reefs. It has been shown that none of the faults or fault systems traversing the reef contains gold in any quantity at a distance of more than a few feet from the reef. Moreover, the relation in plan of fault planes in the reef zone to pay-streaks is such that the faults could not have been the loci for the distribution of gold bearing solutions into the reef. This has been proved by mapping both pay-streaks and faults in detail over about fifteen square miles of reef of the Main Reef group. Many faults, moreover, actually offset pay-streaks and are, therefore, undoubtedly of later origin.

The relation of pay-streaks to folding, faults and dykes is such that, if brought in solution, the gold must have entered the reefs before either folding, faulting or dyke intrusion took place. We may assume that dykes were intruded into the Witwatersrand beds at the very beginning of the Ventersdorp lava extrusions. The batholithic source of the gold solutions must, therefore, have been intruded before the Ventersdorp era during a quiet period of sedimentation, without disturbing the overlying beds by either fracture or dyke intrusion. This is most improbable and contrary to geological experience elsewhere. The distribution of the pay-streaks relative to faulting therefore disproves the infiltration hypothesis.

Redistribution Hypothesis

2. If the gold had entered originally as placer gold, and had later on been dissolved and redistributed on a

large scale within the reef, and if all this occurred after faulting and dyke intrusion had taken place, it is certain that the planes of disturbance would have guided the solutions, causing enrichment in certain areas and impoverishment elsewhere. The distribution of pay-streaks again proves conclusively that such movement has not taken place.

Placer Hypothesis

3. If the gold entered the reefs about the time of their formation and did not come in solution it must have been carried in mechanically as placer gold. The close relation of the sedimentary character of the reef to the distribution of gold in it, as described above, is strong confirmation of the correctness of the hypothesis that gold was deposited as placer with the pebbles.

If the soundness of the placer hypothesis is granted, one must explain the undoubted fact that most of the gold in the reefs shows evidence of having been dissolved and re-precipitated more than once since its primary deposition. The metamorphism of the original sandstones and conglomerates of this system into dense rocks, with an interlocking quartzitic matrix, and the presence of many high temperature minerals of secondary origin such as pyrrhotite, tourmaline and so forth, indicate that, in the course of their long geological history, the reefs were subjected to great accessions of heat and pressure. There was more than one period of dyke intrusion and faulting, and crops of secondary minerals were formed at more than one period. The study of gold distribution over wide areas of reef has shown that the gold solutions did not in any instance move far before re-precipitation took place. Solution of gold grains at points of high pressure and precipitation in near-by areas of low pressure would account for the condition we find the gold in to-day. The conditions which brought about the metamorphism of the silicate minerals in the reef would most assuredly have changed rounded pellets of placer gold in the matrix to their present condition.

MINING METHODS

Over thirty-six million tons of rock were hoisted from the mines of the Witwatersrand in 1928. The ore comes from thin sheets of conglomerate which, although they vary in their gold content, are so remarkably persistent that it has been possible to lay out the mine development with a view to handling very large tonnages of ore. In

1928 there were twenty-five mines on the Rand that crushed more than 50,000 tons of ore per month. Five of these do more than 100,000 and two over 200,000 tons per month.

This condition has made large scale investigations into improvements in the methods of mining and ore reduction possible, and with the free exchange of technical information, that is customary in this field, the results of such investigations have been applied with comparative rapidity to operations over the Rand as a whole.

PROSPECTING

The men who originally prospected the newly discovered reefs found their ore-bodies extending in long outcrops along the valley of the central Rand in an east-west direction and dipping steeply south. Activities began near the centre of the present city of Johannesburg. The outcrops were opened by trenches across the strike, and where payable, along the outcrop. Later on winzes were sunk down the dip and connected by drives along the strike. Further extensions of the ore to the southward were proved by boreholes that were extended farther and farther from the outcrops, and reached the reef at progressively greater depths. In places the outcrops were covered by later formations and here they were also prospected by boring. In this way the great extent of the formation along the strike and in depth was gradually proven.

DEVELOPMENT

To open up the outcrop workings shafts were sunk down the dip of the reefs. These were rectangular shafts of three to five compartments, with their long axes, in cross section, parallel to the reef horizon. Later it was found advisable to sink vertical shafts at some distance south of the outcrops to meet the reef horizon. Compound shafts that were vertical to their junction with the reefs and inclined from there down the dip of the reefs, were in use for some time, but retardation of speed and wearing of the winding ropes at the bend led to their being discontinued.

For mechanical reasons vertical shafts are limited to a depth of 4,500 feet. Where the ores lie deeper, another shaft, situated near enough to the bottom of the first to enable a transfer of rock and ore to be made conveniently from one to the other is sunk either vertically or inclined down the reef as the position of the ore-body may require.

The later rectangular shafts have five and seven compartments. Square and circular shafts have also been

sunk. At great depths incline shafts are usually sunk in the footwall of the reef and the number of compartments decreased to three. Shaft sides are supported by square timbering, or with brick and concrete linings. Vertical shafts are for financial reasons put down at the greatest possible speed and world's records for shaft sinking have been repeatedly broken on the Rand: 386 feet in 31 days on a 23½-foot circular shaft at Randfontein, from depths of 986 to 1,372 feet, and 323 feet in 31 days on a five compartment rectangular shaft on Sub Nigel at depths of 1,000 to 2,000 are both standing world's records.

Stations of the size required for the convenient handling of the ore coming to the shaft are cut at certain levels. Skips are filled from measuring bins in the shaft to the exact load they can carry, and a pair of them hoisted in balance, that is, one is dumping its load while the other is being filled. The ore is automatically tipped into bins in the head-gear from which it is conveyed in trucks or on a conveyor belt to the mill.

From the shafts crosscuts are driven to the reefs and drives in both directions along the reef. Drives are either on reef or in the footwall.

Drives on reef are a convenient means of prospecting their values, but are unsafe at great depths, and are not as efficient for haulage purposes as straighter drives in the footwall. Drives are spaced from 250 to 1,000 feet apart measured along the reef plane according to the dip of the reef. They are connected by winzes and raises which are spaced from 400 to 800 feet apart.

MINING

Stoping commences from the raise and winze connections. Overhead or back stoping, in which the ground is worked out in the shape of a section of a cone is perhaps the most universally employed. Underhand stoping is not so common. Breast stoping in which the face remains more or less parallel to the dip of the reef is usually employed on comparatively flat lying reefs. On steeply dipping reefs the broken rock is for the most part shovelled by natives down the floor of the stope and gravitates into boxes on the level below. As aids to moving the rock fixed and shaking chutes are used. In a few places aerial haulage and scrapers attached to a rope and operated by a winch are also in use. In breast stoping the rock is shovelled into trucks and trammed to a central ore-bin connected to a footwall

haulage, or to a central track from where the trucks are lowered by a winch to the level below.

Where the reef is narrow and partings exist immediately above or below it resuing is sometimes employed. In this method a slice of waste is first removed and packed back into the stope, after which the reef only is blasted and trammed out. (Plate XVIII.) Some form of shrinkage stoping is used in many of the mines.

Formerly nearly all stope drilling was done by hand by so-called hammer boys. The mechanical drills used were heavy and cumbersome to set up. Lately, lighter and more rapidly drilling machines have been introduced and they, and particularly the hand-held Jackhammers, are now generally used in stoping. Breaking efficiency has been increased also by the use of a mechanical "hole director." The proportion of the tonnage of rock hoisted on the Rand that was mined by rock drills, was 90 per cent. in 1928 as compared with 55 per cent in 1918. The tonnage broken per drill per working day was 19.96 in 1928 as compared with 8.10 in 1918.

Support of Excavations

On the whole the reef of the Rand has a strong hanging wall. In the early days pillars were left intact as the main supports in stopes, but to-day they are only employed in special circumstances. They are replaced by cribs or "pigsties" filled with rock or ore. Other means of support are being increasingly employed, depending on local circumstances such as the dip and height of workings, nature of the hanging and pressure and the liability to movement of the hanging. Such means of support are stone packs, concrete monoliths and pancakes, and timber mat packs. Support on a large scale may be obtained by filling the excavation with sand from the reduction plant. In shrinkage stoping and resuing support is directly provided for in the method of working.

As the average depth of workings has increased the labour and cost of supporting the hanging has increased. Rock-bursts become more frequent, and less violent subsidences take place more rapidly with depth. In rock-bursts sudden movements of the hanging wall shatter the faces of pillars, or remnants of reef, and break up the hanging and footwall in their vicinity. The scheme of development, and in some cases of mining, has to be altered, and more efficient means of support have to be used. As a measure of the increased cost it may be

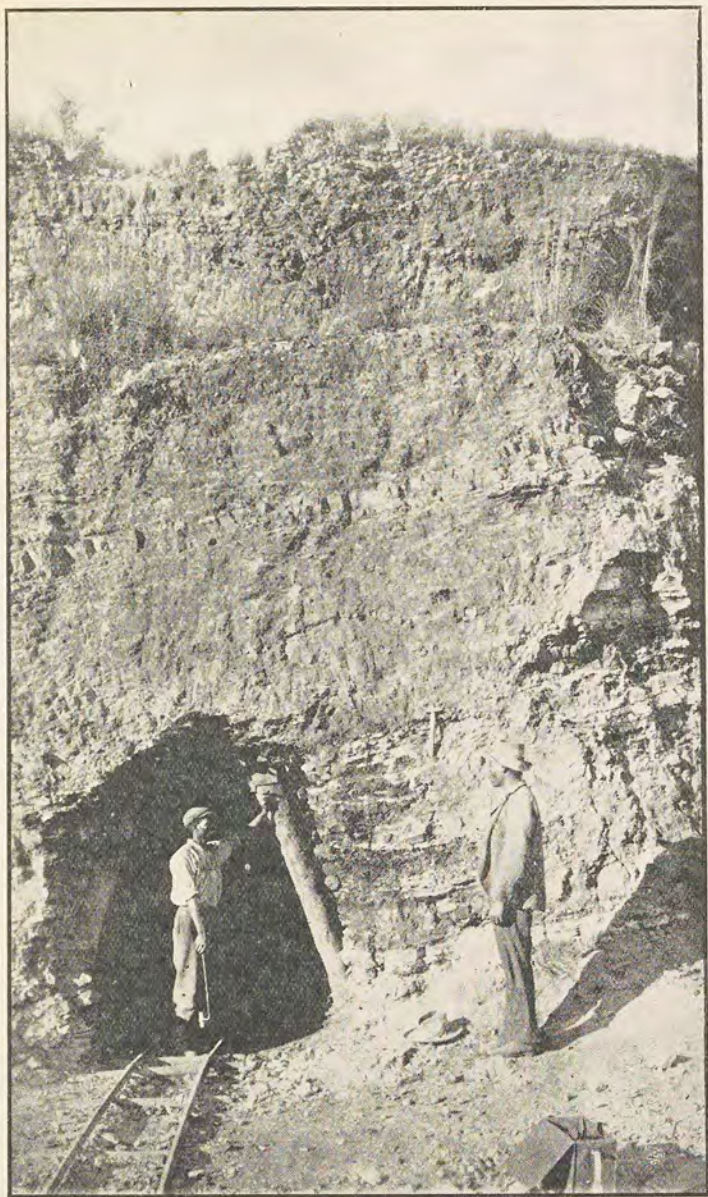


Plate XXII.—East Clewer mine adit, Pilgrims Rest, showing the interbedded Theta reef (from hammer down to foot of post) lying in soft residual dolomite.

[Photo, A. W. Rogers.

stated that the number of natives employed in support of the hanging has doubled in the last twelve years.

Large plantations of gum, wattle and other trees have been established primarily, and in many cases solely, for the purpose of supplying the timber used for support of mine workings on the Witwatersrand.

Transportation

From stope boxes the ore is loaded into trucks and trammed by hand or mechanical means to the shafts. For short distances over well graded tracks, hand tramping is economical and a large tonnage is moved by this means. Mule and horse transport is used on a few mines only. Other means of transport are "Main and tail" and "Endless rope" haulages.

For hauling loads over long distances electric locomotives are more commonly employed. They are either of the trolley type operating from a wire attached to the hanging of the drive, or of the storage battery type. Mechanical tiplers are employed at stations underground and on head-gears.

As speed in hauling is an important consideration winding engines have been constantly enlarged and improved. Electric hoists are preferred because of their greater speed, while steam driven hoists have the advantage of possessing an independent source of power. On the mines of one of the large groups on the Rand the percentage of electric hoist is 76, steam 20, and air 4. The largest winding engine on the Rand is that on No. 4 shaft of the City Deep mine. It is capable of lifting $9\frac{1}{4}$ tons from a vertical depth of 4,500 feet at a speed of 3,700 feet per minute (42 miles per hour).

Drainage

The water in the mine workings is drained into sumps from where it is collected by reciprocating pumps into main settling sumps. From these the clear water, after its acidity has been neutralized, is lifted to the surface. The mud is pumped into a skip or passed through a filter press. The resulting mud cakes are then taken to the ore-bins. Multi-centrifugal pumps are used on the main pumping stations. The largest pump on the Rand is a Sulzer Multi-centrifugal pump at the Simmer and Jack mine. This pump delivers 75,000 gallons per hour against a manometric head of 3,256 feet. This is probably the highest lift of any pump in the world.

The Francois cementation process has been much used of late years for damming back water and saving pumping

costs. The process consists of pumping cement under pressure into crevices and interstices in the rocks. It has been found useful for sealing off water-bearing fissures that are being passed through in development.

Ventilation

The Mining Regulations require that for every person underground at least 30 cubic feet of air per minute shall pass the working faces throughout the 24 hours. It is required that the mine air shall not contain over 20 volumes of CO_2 per 10,000, 1 volume of CO per 10,000, and that oxides of nitrogen shall be practically absent. Blasting is allowed to take place once in 24 hours only. Special ventilation must be supplied and water blasts must be used at the time of blasting and afterwards. Men have to leave the mine at blasting time and must not re-enter it until the expiry of an interval fixed for each mine by the inspector of mines.

Special ventilation shafts have been sunk to serve large areas. Centrifugal fans are used for large scale ventilation and these act either as pressure or exhaust fans. One of the largest fans in use is capable of circulating 900,000 cubic feet of air per minute through the mine at a water gauge of 7 inches.

The regulations require that the mine shall have an official whose duty it is to report on the water supply, sample the air for its dust content, and report as to the volume of air circulating through the workings per minute and its CO_2 content. The dust content causes a disease called Miners Phthisis, which is referred to again farther on in this chapter. To check the incidence of this disease every effort is made to prevent the formation of dust and its escape into the air. For this purpose water is fed through hollow steel bits in drilling and sprays and water blasts are used near working faces.

Special drinking water is always supplied underground. Care is taken in sanitation. Latrines are provided and kept clean. To prevent the spread of the disease known as hookworm salt is spread liberally around these places.

SURVEY AND VALUATION

Survey and Sampling departments are maintained by each mine. The Chief Surveyor is responsible for all measurements, plans, correct directions and statistical returns regarding quantities and values. The technical skill of the surveyor in these fields is proverbial. The work done and the records kept by the Sampling department are unique in the detail provided for every develop-

ment and working face in the mine. The results provide data for a very fair approximation of what may be expected from the mill.

ORE REDUCTION.

In the course of forty years of practice the reduction of ore on the Rand has been vastly improved from the time when only 65 per cent. of the gold in the ore was obtained to the present extraction of 97 per cent. Amongst the factors that have helped to bring about this improvement are the development of the cyanide process of gold extraction, improvements in milling such as the introduction of finer grinding by tube mills, filters for treating slime and so forth. The following synopsis of the general process is based on the procedure at one of the Central Rand mines. (Figure 6 and Plate XIX.)

The ore that is tipped out of the skips coming out of the shaft goes over bar grizzlies where the big lumps are separated from fines.

CRUSHER STATION.

From here it is conveyed to the crusher station in trucks by endless rope haulage or by electric and steam locomotives. The locomotives haul trucks with capacities up to 40 tons. The fines go directly to stamp mills. The coarse material is broken in jaw and gyratory crushers to a maximum size of about 6 inches, is washed and passed over conveyor belts where the waste rock is picked out by hand. The waste rock is conveyed to the dump. Big lumps of 4 to 6 inches in the ore are separated out by trommels and afterwards used as grinding pebbles in the tube mills. The rest goes to Gates crushers where it is reduced to about 2-inch size. From here it goes directly to the stamp mill.

STAMP AND TUBE MILLS.

In the more modern mills on the Rand gravity stamps vary in weight from 1,500 to 2,000 lb. The ore is crushed wet to pass screens that vary in size up to $1\frac{1}{4}$ inches. The larger batteries consist of as many as 600 stamps. The weight of the stamps has gradually increased from 750 to 2,000 lb. The tonnage crushed per stamp has risen from 2 tons to 15 and 30 tons per day. This is due in part to increased weight and also to the fact that crushing is not so fine, finer grinding being accomplished in tube mills. Formerly stamp mills ground the ore to pass a 600 mesh screen, now they are as coarse as $\frac{1}{2}$ -inch to 1-inch. From the mortar boxes of the stamp mills the

pulp goes to classifying cones. The underflow of the cones goes to the tube mills. These are about 22 feet by 5½ feet with renewable liners. The grinding is done by large fragments of ore separated out at the crusher station for that purpose. In some of the newest plants to-day stamps are eliminated and the ore passed from the rock breakers directly to tube mills which have a capacity of up to 200 tons each per day.

AMALGAM ROOM.

The pulp from the tube mills passes over corduroy cloth where gold, osmiridium and the heavier minerals such as pyrite are collected. The corduroy is taken up every four hours and the concentrate washed off into a receptacle from which it passes over a shaking table. The concentrate from the table is ground with mercury in an amalgam barrel where the gold is caught by the mercury. Excess mercury is squeezed out and the amalgam is then retorted. The mercury vapour is condensed and used again. The gold is smelted and cast into bars. The portion in the barrel that does not amalgamate contains the valuable constituent osmiridium, which is recovered by further concentration over shaking tables.

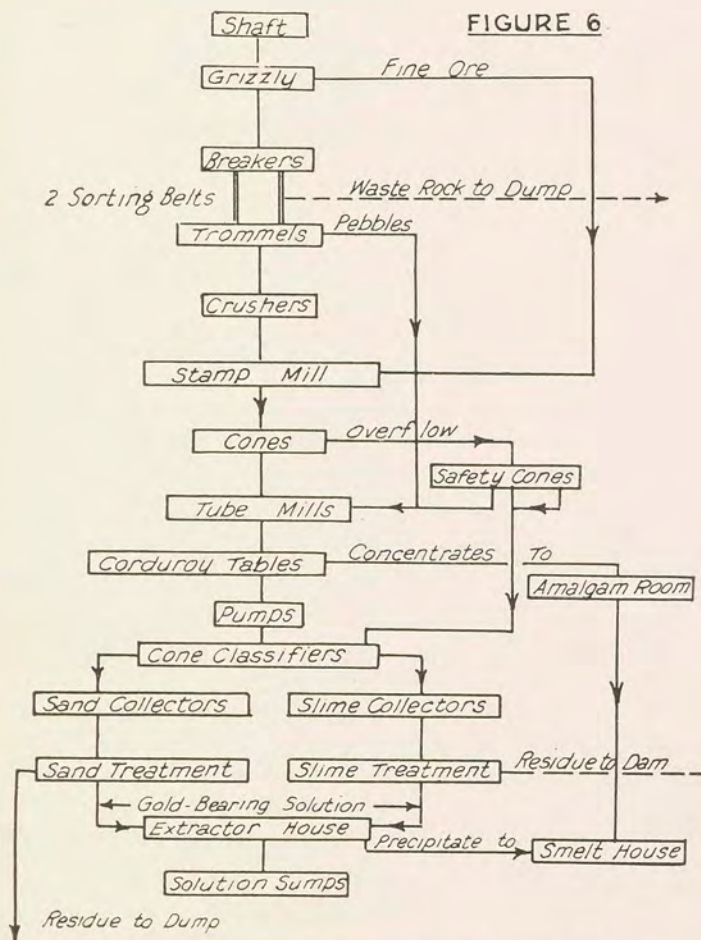
Corduroy tables have superseded the use of mercury amalgamation tables in which gold in very finely divided condition is passed over tables surfaced with copper plates coated with mercury, from which the mercury gold amalgam is afterwards scraped and the mercury retorted off. In most of the recently erected plants even the corduroy tables are omitted and all of the gold is recovered in the cyanide plant.

CYANIDE PLANT.

The overflow from the tables and the cone classifiers in the crushing plant passes to cone classifiers where it is separated into "sand" and "slime." Slime is that portion of the crushed product of which 90 per cent. or more consists of particles less than 0.003 inches in diameter. It contains a great deal of colloidal or jelly-like material and will not allow liquid to percolate through it without artificial pressure. Sand is the coarser portion through which liquid will percolate. In modern plants about 60 per cent. of the pulp is separated out as slime. In still others all of the pulp is reduced to slime and sand entirely eliminated.

The sand flows from the classifiers into collector vats each of about 400 tons capacity. Here the water drains

FIGURE 6



— Flow Sheet of Reduction Works on a —
 — Central Rand —
 — Mine —

(After B. G. Orpen)

off through a filter mat in the bottom. In some cases the treatment is completed in these vats in others the drained sand is taken over a conveyor belt to the treatment vats. There the gold is treated with solutions of sodium cyanide (formerly potassium cyanide) to a maximum strength of about 0.05 per cent. The solutions percolate through at the rate of about 900 tons of solution in seven days. They pass through a filter mat at the bottom and from there to the extractor house. The leached sand goes to the dump.

After the addition of lime in the proportion of 3 lb. to 1 ton of slime the overflow from the cone classifiers goes to a collecting vat where the slime is allowed to settle and the clear water is returned for further mill use. The settled slime with cyanide solution is transferred to another tank or vat where it is agitated by being passed through a pump. In this vat the solution is present in the proportion of 3.7 to 1 of dry slime. The solution varies in strength from 0.005 per cent. upward. The slime is transferred to treatment tanks where it is allowed to settle and the gold-bearing solution is drawn off. The settled slime is retreated in the same way in a second vat and after settling the "second wash" gold-bearing liquid is drawn off and the slime goes to a residue dam. In recent plants Brown vats or Dorr agitators are used for dissolving the gold and the rich solution is separated by Butters or Oliver filters.

EXTRACTOR HOUSE.

The gold-bearing liquid from the first and second treatments is sent to the extractor house. In the extractor house the solutions are allowed to pass slowly through long boxes 5 to 6 feet in width, densely packed with thin filaments of zinc. The gold is precipitated on the zinc. Periodically a portion of the zinc shavings is removed and treated with sulphuric acid or bisulphate of soda. The zinc is dissolved as zinc sulphate and the gold together with certain impurities is left behind as a black mud. In the latest plants zinc dust is used to precipitate the gold and the barren solution is separated by means of Merrill filter presses or filter vats, after having its dissolved oxygen removed by passing through the Crowe vacuum process. The treatment of the separated gold-bearing zinc dust is similar to that of zinc shavings. The gold-bearing residue after washing and passing through a filter press is ready

for smelting. The cakes of gold slime are charged into a calciner where they are raised to a red heat and the moisture driven off. The cakes are then mixed with a flux of borax, sand and manganese dioxide, and smelted in graphite crucibles in reverberatory furnaces. From the crucible the molten material goes into cone shaped moulds and in these the gold collects as buttons. After separation from the slag the gold is smelted and cast into bars of from 800 to 1,000 ounces each. In this form it is sent to the Rand Refinery. The flow sheet of the plant of one of the mines on the Central Rand is shown.

RAND REFINERY

A gold refinery was established near Germiston on the Rand in 1921. This is the largest of its kind in the world, and more than one half of the world's output of gold is handled there. The operating company is under the control of the Transvaal Chamber of Mines.

The bullion produced in the smelting houses of the mines is carried in special lorries under armed guard from the mines to the refinery. Upon its receipt at the refinery the bullion (which contains silver and base metals as well as gold) after being sampled and assayed, is melted and the silver and base metals removed by passing chlorine gas through the melt. (Plate XX.) The silver is afterwards removed from the mixture of chlorides of silver and base metals. The average fineness of the gold produced is 995.6 and of silver 998.3.

From December 22, 1921, to September 30, 1929, a total of 83,038,941.37 ounces of bullion was received by the refinery which contained 79,679,030.02 ounces of standard gold and 7,303,232.74 ounces of fine silver. The bullion issued during that period contained 72,903,346.1 ounces of fine gold and 7,304,472.93 ounces of silver. That is 2,504 short tons of gold and 250 tons of silver.

The following data as to operations in 1926 will indicate where the gold and silver are marketed.

The fine gold delivered amounted to 10,684,845.05 standard ounces, and was disposed of as follows:—

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

Ounces:	Consigned to:—
225,247.49	London on account of the Mining Industry.
1,525,892.34	India on account of the Mining Industry.
5,019,181.26	London on account of the South African Reserve Bank.
368,079.99	India on account of the South African Reserve Bank.
3,283,297.55	Royal Mint, Pretoria on account of the South African Reserve Bank.
263,146.42	Sundry Local Sales.
The value at 77s. 10½d. per standard ounce was £41,604,116.*	

The fine silver delivered amounted to 980,294.40 fine ounces, and was consigned direct to India.

The collection of bullion from the mines in that year amounted to 11,000,933 ounces—approximately 377 tons.

WATER SUPPLY

A broad strip of dolomite of the Transvaal system outcrops a few miles south of the line of mines, and dolomite areas occur on the eastern and western ends of the field. Vast reservoirs of water occur in underground cavities within the dolomites and they have until recently been the main source of the water used upon the Rand. Water was first obtained from one of these cavities in 1898. Between 1905 and 1910 about 2½ to 4 million gallons was pumped from these stations. From about 1910 to 1923 the amounts ranged from 8 to 10 million gallons per day. In addition about 6 million gallons of water are pumped daily from mines lying within the dolomite basin of the Far East Rand but only a small portion of this is used.

Since 1923 water has been obtained from a barrage in the Vaal River which lies about 40 miles south of Johannesburg. The amount impounded is 13,633 million gallons of which the effective supply available for the Rand is 7,300 million gallons. Pumping facilities are available for carrying 10 million gallons a day to service reservoirs on the Rand.

The average quantities obtained from these sources during 1926 was 12.60 million gallons per day.

* For certain purposes gold is calculated in "standard" ounces. 1,000 ounces of "standard" gold contains 916.66 ounces of pure or fine gold.

FUEL

Overlying the formations of the Witwatersrand-Ventersdorp and Transvaal Systems over wide areas on the East Rand and in small patches elsewhere are the lower beds of the Karroo System which carry workable seams of coal in many places. Coal has been actually mined within the gold mining area as far east as Boksburg and it is being mined in the vicinity of the gold mines on the Far East Rand to-day. The Rand's main supply of fuel is derived, however, from the mines at Witbank which lie some 90 miles by rail to the north-east of Johannesburg.

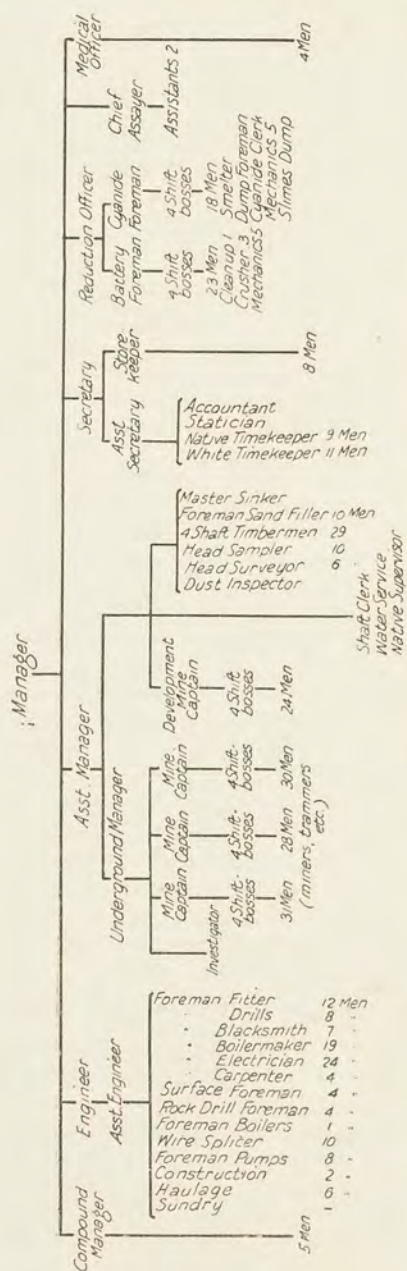
The mines consume an average of about 4,400 tons of coal per day or 1,606,000 tons per year. The value of the coal and coke consumed in 1928 was £965,841.

POWER

Most of the power used in mining and the reduction of ore is electrical, but steam is also employed. The Victoria Falls and Transvaal Power Company with stations at Rosherville and Vereeniging supplies electrical power to all but three mines on the Rand. They also maintain central compressor plants from which 5,000 tons of compressed air are supplied each day to the mines. In addition many mines have their own compressor plants. Where only electrical power is used the consumption is about 50 units of electricity and 16 units of compressed air per ton of ore milled. One unit of compressed air is equal to about 444 cu. feet of free air. The total supplied by this Company is 1,000 million units of electricity and 150 million units of compressed air per annum at a cost of 0.4 pence per unit of electricity and 0.5 pence per air unit where obtained from the pipe system on the central Rand. Three mines have their own electric plant.

ORGANIZATION

There are forty-one gold-producing companies on the Witwatersrand at the present time, ten of which are either small concerns or large mines cleaning up at the end of their life. Of the thirty-one remaining mines each has its own Board of Directors, but they are controlled and administered, with two exceptions, by a few large corporations, locally known as Groups. The Groups hold large share interests in the individual companies they



— Organization of European Personnel on a Central Rand Mine —

FIGURE 7

(After K. J. MacWilliam.)

control, but they do not necessarily hold controlling interests. Their control is exercised by virtue of an adequate representation on the Boards of Directors.

Groups maintain a staff of technical specialists in mining, mechanical, and electrical engineering, in metallurgy and so forth. These men serve the mines controlled by the Groups at a cost lower than if the mines engaged them individually. They assist in co-ordinating technical practice and in investigating means of increasing the efficiency of mining operations. The Groups act as secretaries for the individual companies. They keep share registers, arrange insurances, handle land and claim transactions and questions of taxation, compensation, etc. Their buying departments purchase all supplies for individual mines, and they perform other services.

The costs of head office and administrative expenses to the mines amount to about 6d. per ton milled. Outside of administrative work the Groups lend financial aid to the mines under their control, they investigate new mining fields and promote new companies.

The Transvaal Chamber of Mines is an association of the gold and coal mining companies of the Transvaal to promote their mutual interests. Its executive powers in connection with gold mines are exercised by the Gold Producers Committee composed of representatives of the Groups. The Chamber of Mines has no executive authority over the Groups or individual mines. It concerns itself with matters affecting the industry as a whole. These are employment conditions and industrial relationships, government control, the prevention of accidents and of phthisis, the supply of native labour, the management of the Rand Refinery and of the Rand Mutual Assurance Co., which insures mine employes against accident and death.

The expenditure on the Chamber of Mines organization and the subsidiary industries it supports is distributed over the individual companies at cost.

In the following diagram the scheme of organization of the personnel of one of the mines in the Central Rand is given. The diagram is self explanatory. Variations in organization obtain from mine to mine. These are governed by factors such as the size of the mine and other conditions.

LABOUR

EUROPEAN

There were 22,000 persons of European descent employed by the gold mining industry on the Rand in 1928 and about 195,000 natives and other coloured persons. These received a total of £14,567,237 in wages.

Of European employees 10,167 were employed underground, this is nearly the same number as in the year 1910. Omitting the year 1922, during which the mines were only in operation for nine months owing to the strike, the number employed underground for the last eighteen years has varied from 7,937 to 11,600. In the early days of mining on the Rand the vast majority of miners were men of overseas birth drawn from older mining communities. Since 1907 there has been a steady increase in the numbers and relative proportions of South African born miners drawn mainly from agricultural districts, so that to-day these constitute 70 per cent. of the working white miners. The tonnage hoisted per native labourer underground has remained practically stationary. The tonnage hoisted per white labourer underground has increased from 8.43 per day in 1910 to a maximum of 12.8 per day in 1924. In 1928 it was 11.58 tons per day. Although this increase is in a measure due to improvement in the efficiency of mechanical means of breaking and transporting ore, it also indicates an increase in the efficiency of the white miner. The careful medical examination and selection of candidates for work underground since 1917 has, moreover, brought an increasingly large proportion of men of a sound physical standard underground, men who under test have proved to be more capable of withstanding the conditions of such work than their predecessors.

The average rate of pay for all officials, clerical, and other monthly paid employees was £35 15s. 5d. per month in 1914, and £40 14s. 0d. in 1929. The average wage of "day's pay" men including mechanics, engine drivers, reduction workers, miners and sundry was 18s. 5d. per day in 1914, and 22s. 3d. in 1929. European employees work a 48 hour week and only special and emergency work is carried out on Sundays. The men receive annual leave on full pay (not exceeding 22s. per day) after one year's service. Their leave varies from 14 to 28 consecutive days for underground workers and 14 days for surface workers.

Officials receive from three weeks to one month annually and in certain cases longer leave, at intervals of some years.

Housing accommodation is provided for some of the white employes on mining properties, and practically every mine property on the Rand has recreation halls and facilities for outdoor sport, such as lawn tennis, football, swimming, golf, and so forth.

There is a Sick Benefit Society on every mine into which employes pay a monthly fee for which they and their families receive medical attention.

In addition to this, claims for injuries received while at work on the mines are dealt with by a special company, the Rand Mutual Assurance Company, Limited, in which all but two of the mining companies on the Rand insure their employes.

For the benefit of young men who wish to become miners the Government Miners' Training Schools have been established, where they are given a two-year course in practical mining. Those who take the course received enough pay to maintain themselves. About 500 apprentices attend these schools. In 1927 the cost of training each apprentice per day was about 5s. 9½d. This is borne partly by the Gold Mining Industry and partly by the Government. To boys who have reached the matriculation stage in their school education, the mines offer a course as "official learners." This course is intended to give a learner practical experience of each of the departments of a mine, and to fit him eventually to carry on the duties of an underground official. Finally a five-year course in Mining Engineering, part of which is spent in practical work underground, may be had at the Witwatersrand University in Johannesburg.

NATIVE

The native labour complement required by the gold mines varies from time to time; in June, 1929, it was 206,000. Two organizations, the Witwatersrand Native Labour Association and the Native Recruiting Corporation, with headquarters in Johannesburg, are employed to keep this army up to strength.

The Witwatersrand Native Labour Association recruits labour in Portuguese East Africa, south of latitude 22 degrees S. It employs 95 Europeans and 771 Natives for this task. It has stations systematically placed throughout the territory to which natives come seeking work. From

these they are sent by stages to main camps in the Union and eventually by way of a central depôt in Johannesburg to the various mines. The natives undergo no less than three medical examinations *en route*. Recruiting is entirely voluntary. The Portuguese natives have worked in the mines for thirty years until mining has become a tradition. The native goes to the mines in order to get the wherewithal to pay his *lobola* or marriage portion, to pay taxes and to buy the many things that contact with the white man has taught him to use. There are about 200,000 adult natives fit for heavy work in the territory, and while only 12,000 natives suffice for local labour requirements, the mines take about 103,000. The natives contract to remain for twelve months after which they may renew their time for an additional six months.

The Native Recruiting Corporation gets its natives from the Union and the British native territories of Bechuanaland, south of latitude 22 degrees S., Swaziland and Basutoland. They employ 57 Europeans, 127 natives and 413 white recruiting agents for the work. The latter are usually traders who are licensed and supervised by the Government and the Corporation. About one half of the natives from these countries come to the mines on their own account. There are about 1,026,000 adult male natives in the Union available for work, and 230,000 in the territories, and of these something like 1,000,000 are in continuous employment other than on their on affairs. Of this number the mines obtained 103,958 in 1928. The natives contract to remain for 270 working days. The cost of recruiting is 1.658 pence per native per shift worked.

From the central depôt in Johannesburg the natives go to the various mines. There they live in compounds, where strict cleanliness and decency is insisted on. They are amply fed and well cared for when sick. Religious instruction is arranged for and night schools are maintained. The playing of games in the open air is encouraged, and cinema entertainments are regularly given.

The ration enforced by Government regulation is as follows: 24 oz. of maize meal, 6 oz. bread, 3 oz. of beans or peas, 2 oz. of peanuts or $\frac{1}{2}$ oz. of fat, 5 oz. of vegetables $1\frac{1}{5}$ oz. of coffee or cocoa with sugar, per day, and in addition $3\frac{3}{4}$ lb. of meat per week and sufficient salt.

Each mine has a well equipped native hospital and 34 medical officers are employed on the Rand who devote all their time to native labourers on the mines.

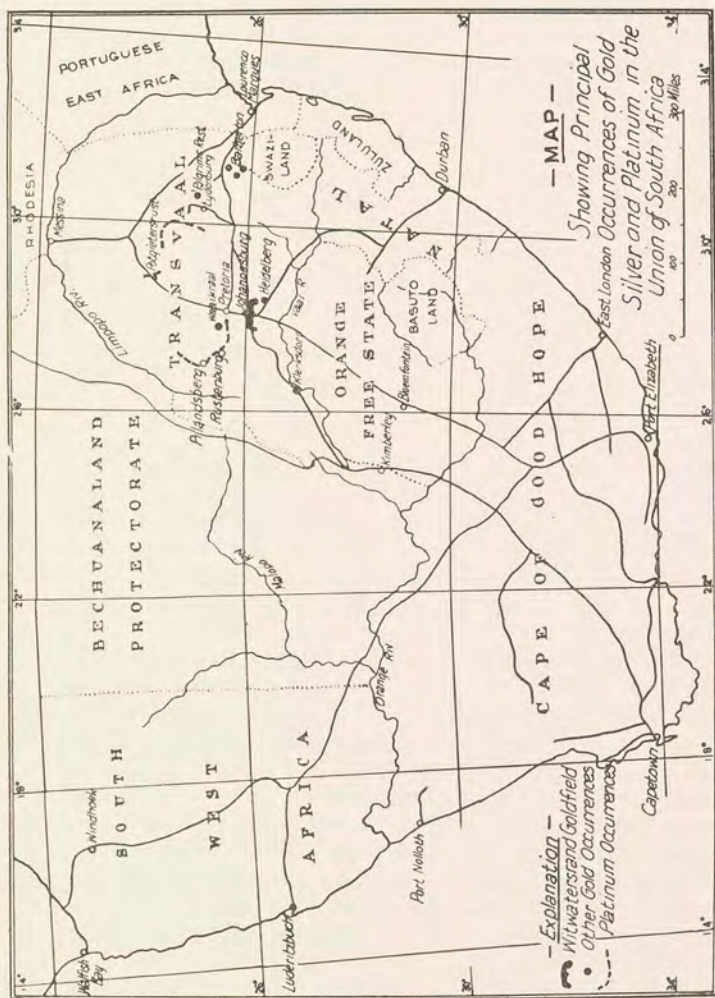


FIGURE 8.

Six doctors are maintained at the central dépôt in Johannesburg from where sick and injured natives are sent back to their homes under special supervision.

The natives earn from 2s. to 2s. 10d. per shift, and food, quarters, medical attention, etc., is given them free, at an additional cost to the mines of about 1s. 6d. per diem. There are facilities for transmitting money home to their friends, and, under a deferred payment scheme, many of them get the bulk of their wages on arrival back at their huts.

The Industry has contributed £46,506 to build the South African Institute for Medical Research and contributes £7,500 annually towards its maintenance. They contribute also £4,000 per year for three years to research on tuberculosis.

Deaths amongst mine natives from disease have dropped from 28·02 per 1,000 in 1909 to 9·45 per 1,000 in 1928.

MINERS' PHTHISIS

When very fine silica dust is inhaled into the lungs over a long period of time, it tends to produce abnormal fibrous tissue analogous to scar tissue in those organs. This is "simple silicosis." Simple silicosis does not cause serious disablement, but the abnormal spots are more prone to infection from tubercular bacilli and other causes than the normal lung tissue, and such infection gives rise to "infective silicosis." These two conditions constitute Miners' Phthisis. The disease tends to advance rapidly after infection.

In the early years of the Rand the workings were shallow, cool, and artificial ventilation was not thought necessary, much less was any attempt made to lay the enormous clouds of dust formed by dry drilling and the handling of the ore. About the years 1902 and 1903 it began to be realized that miners working with rock drills were suffering from a lung disease contracted in the mines. It was found that 16·5 per cent. of those engaged in rock drilling before 1899 had died of this disease. The first Phthisis Report was published in 1903, and the first Government Act to aid in its prevention was passed in that year. From that time to the present there has been an unceasing campaign towards the prevention of the disease.

Sir Robert Kotze, the former Government mining engineer, was the driving force in this campaign and his invention of the Konimeter for counting the dust particles

enabled more effective measures to be taken for detecting and preventing the accumulation of excess dust in mine air. As a result of the activities of his Department there are detailed legal regulations to enforce measures for the prevention of dust underground.

Constant and systematic sampling of the air and inspection of ventilation conditions is undertaken in every mine. Every European and native employe underground is medically examined at definite periods and investigational work in connection with the disease is in constant progress.

The measures that are in vogue for the prevention of phthisis at present are principally aimed at keeping down the quantity of dust in the air so as to prevent simple silicosis and the minimizing of the chances of tubercular infection.

The inhalation of dust by workers underground has been minimized during the last sixteen years by improved attention to ventilation as described under "Mining Methods," by strict regulations in regard to the time and manner of blasting, the use of water for drilling holes, the control of the types of drills that may be used, the wetting of all underground rock surfaces and broken rock in places where men are working, and the installation of sprays at all tips and ore passes.

The examination of air samples by dust inspectors in the mines has shown that these measures have eliminated practically all coarse dust and reduced, but not entirely eliminated, the microscopic dust that causes silicosis. Since 1917 medical examination of white candidates for work underground is so thoroughly done that only forty per cent. of those examined are passed. This is intended to eliminate all of those who would tend to contract tuberculosis. Europeans working underground are examined every six months by the Miners' Phthisis Medical Bureau, and when they show signs of infection are prevented from further work underground. Natives are also periodically examined by the mine medical officers, but the process followed is somewhat different. The result of all these measures is that the number of new cases of silicosis and attendant tuberculosis has dropped from the former very high rate to an average of 2.66 per cent. of the working white miners underground over the last ten years. In 1927-8 it was 1.76 per cent. The men who have come into the industry since strict medical examination has

precluded those of weak lungs show much less tendency to contract the disease. In spite of the progress made, however, the problem is still a serious one.

The Mining Industry pays compensation to those who have contracted Miners' Phthisis, according to their wages and the stage to which disease has developed. The compensation varies from about £400 to £3,500 for each man suffering from the disease. Since August, 1919, the Industry has contributed £800,000 per year to meet this, or an average of 7s. 6d. for each white underground-shift worked.

PREVENTION OF ACCIDENTS

The death rate from accidents on the Witwatersrand has decreased from 4.10 per 1,000 in 1911 to 2.29 per 1,000 in 1928. This is due in part to the work of the "Prevention of Accidents Committee" of the Rand Mutual Assurance Company, Limited, of which Sir Robert Kotze was chairman, and which commenced its operations in 1912. Its activities included inquiries into the causes of accidents, examination of safety devices, safety propaganda and the training of underground employees in "First-Aid" work. A large part of the credit for lessening the number of accidents is due to the work of the Government Department of Mines, who have framed exhaustive regulations with a view to the prevention of accidents and disease underground, and who employ a staff of inspectors to see that these regulations are strictly enforced.

GOVERNMENT LEASES AND PROFITS

The original mining laws of the Transvaal allowed one individual to peg up to a maximum of 50 claims of 150 x 400 feet on mining land proclaimed as gold-bearing, after the allotment of owners' and discoverers' rights. After the outcrop areas had been taken up and worked, it was found that the extensive areas of Rand ore-bodies of low grade, lying down the dip from the outcrops, and their great depths in some places from the surface, made economical mining possible only to companies of sufficient financial strength to undertake the great expense of development. The older laws as to claim rights were unfavourable to sound mining, for it allowed of much trading in claims too small to work and raised the initial price of the ground to be mined above its intrinsic value. An Act was therefore passed in 1908 under which a Mining

Leases Board was instituted, of which the Government Mining Engineer was chairman. The Board was empowered to call for tenders and lease such areas of gold claims as would, in the opinion of their chairman, constitute a workable mining proposition. Small areas lying next to working mines can under the Act be leased to such mines as are in the best position to work them. The lessees had to give guarantees of their ability to develop and work the claims, and they have to pay a percentage of the profits to the Government.

Sixteen areas have been so leased on the Rand and in the case of six of the operating companies the Government's share of profits varied from 1·4 to 10·8668 per cent. In other instances the Government's share of profits is calculated upon a sliding scale so devised that the company receives a fixed proportion of any reduction in costs it may make and another fixed proportion of any increase in recovery it may effect, subject in some of the leases to minimum percentages. The general form of the sliding scale is $y = a - \frac{b}{x}$ where y is the profit payable to the Government, x the ratio of profit to recovery expressed as a percentage, and a , b are constants agreed to in the lease. Besides leases granted under the terms mentioned, others have been sold either for cash, or for annuities over a term of years, or payments on a royalty basis.

The revenue accruing to the Government from leases of this kind up to March 31, 1929, is as follows:—

From leases, on a basis of participation	
in profit	£15,477,973
From leases, sold for cash	326,022
From leases, sold on an annuity or	
royalty basis	1,874,113
	17,678,108
Less amount paid to freeholders ...	1,624,262
	<u>£16,053,846</u>

The present annual income from this source is about £2,500,000.

COSTS AND PROFITS

On the Witwatersrand costs are calculated for the most part on the basis of tons milled. The average cost

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

per ton milled for the year 1928 for the whole Rand was 19s. 9d. The following table gives details of the cost per ton milled for the year 1928 for two mines on the central Rand, each of which milled close to 900,000 tons during the year:—

Details of costs per ton milled—year 1928:—

					Mine 1.		Mine 2.	
Tons Milled	...	...	...	...	898,200		918,400	
Mining	...	...	...	...		s. d. 11 6-54		s. d. 10 10-24
					s. d.		s. d.	
Stoping	...	...	...	...	3 2-04		2 11-90	
Reclamation	...	...	...	...	4-50		4-70	
Sand filling	...	...	...	...	1-55		3-25	
Timbering and Packing	...	...	...	...	1 9-85		1 9-39	*
Ventilation	...	...	...	...	1-86		2-00	
Hoisting	...	...	...	...	1 6-73		1 5-92	
Shaft maintenance	...	...	...	...	2-90		3-76	
Tramming and Shovelling	...	...	...	...	2 7-68		2 5-67	
Dust allaying	...	...	...	...	2-90		1-81	
Underground supervision	...	...	...	...	8-78		4-60	
Assaying	...	...	...	...	0-25		0-28	
Surveying	...	...	...	...	0-65		1-23	
Sampling	...	...	...	...	1-07		1-09	
Underground sanitation	...	...	...	...	3-11		2-12	
Head Office fees	...	...	...	...	0-67		0-52	
Pumping and Baling	...	...	...	...		8-08		8-07
Sorting and Breaking	...	...	...	...		2-70		2-95
Surface transport of ore	...	...	...	...		3-30		3-64
Ore reduction	...	...	...	...		2 8-56		2 11-16
General expenses	...	...	...	...		1 6-32		1 7-05
Head, London and Paris offices	...	...	...	...		2-37		2-91
Development expenses	...	...	...	...		1 10-31		2 10-33
						18 11-98		19 8-35
Expenditure on renewals and replacements to Plant and Buildings	...	...	...	...		0-39		0-15
Total	...	...	...	...		19 0-37		19 8-50
					Per Ton Milled.		Per Ton Milled.	
					s. d.		s. d.	
White wages	...	...	...	...	5 5-64		4 6-17	
Native wages	...	...	...	...	3 9-80		3 11-60	
Stores	...	...	...	...	6 2-82		9 3-37	
Sundries	...	...	...	...	3 6-11		1 11-36	
Total	...	...	...	...	19 0-37		19 8-50	

In the following table the average working costs per ton milled on the whole of the Rand show a progressive increase from 1910 to the years 1921-2 of from 17s. 7d. per ton to 25s. 8d. From then on there was a decline to the end of 1926, and a slight increase in the last two years. The decline in costs is to be ascribed to progressive efficiency in mining methods, especially in the matter of

drilling and blasting, from 1922 onward. This is being counteracted at the present time by the increased cost of mining at the great depths, 5,000 to 7,000 feet, which obtain in certain of the mines on the central Rand. This applies especially to hoisting the ore to the surface, which, in certain mines, has to be done in three stages, and, to a lesser extent, to the extra arrangements for ventilation and support of the hanging. The cost of ore reduction has been brought down to the low figure of approximately 3s. per ton milled.

The following figures are taken from the returns of the Chamber of Mines:—

Year.	Tons Treated.	Recovery.	Working Costs (as Declared by Chamber of Mines).		Balance of Recovery (Working Profits.)	
			Total.	Per Ton.	Per Ton.	Total.
	£	dwt.	s.	d.	s.	d.
	£					
1910	21,543,866	30,563,359	6.680	28 4	17 7	10 9
1911	23,991,284	33,407,654	6.577	27 11	18 0	9 11
1912	25,657,235	36,909,200	6.793	28 10	18 8	10 2
1913	25,728,165	35,628,828	6.542	27 9	17 11	9 10
1914	25,732,967	34,064,403	6.233	26 6	17 1	9 5
1915	28,355,179	37,200,568	6.177	26 3	17 5	8 10
1916	28,542,650	38,038,008	6.275	26 8	18 1	8 7
1917	27,271,296	36,935,139	6.377	27 1	19 2	7 11
1918	24,938,990	34,776,014	6.566	27 11	21 7	6 4
1919	24,059,960	38,168,826*	6.730	31 9	22 11	8 10
1920	24,155,305	44,407,544*	6.578	36 9	25 8	11 1
1921	23,437,196	41,998,399*	6.762	35 10	25 8	10 2
1922	19,585,920	31,334,125*	6.935	32 0	23 6	8 6
1923	26,765,126	40,446,239*	6.651	30 3	20 0	10 3
1924	28,527,010	43,495,614*	6.526	30 6	19 7	10 11
1925	28,659,217	39,596,401	6.505	27 7	19 2	8 5
1926	29,742,630	40,978,750	6.487	27 7	19 0	8 7
1927	29,397,985	41,207,230	6.600	28 0	19 7	8 5
1928	30,218,533	42,005,741	6.545	27 10	19 9	8 1

* Including premium on gold.

The working profit of £12,164,940 is not all available for dividends to shareholders. A large portion of it is absorbed by such items as interest and redemption of loans and debentures, Government's share of profit, Union and Provincial taxation, oversea taxation, capital expenditure, realization charges, directors' and auditors' fees, depreciation, donations, etc. The methods of keeping accounts on the mines is not uniform, and some of them include certain of these items in working costs.

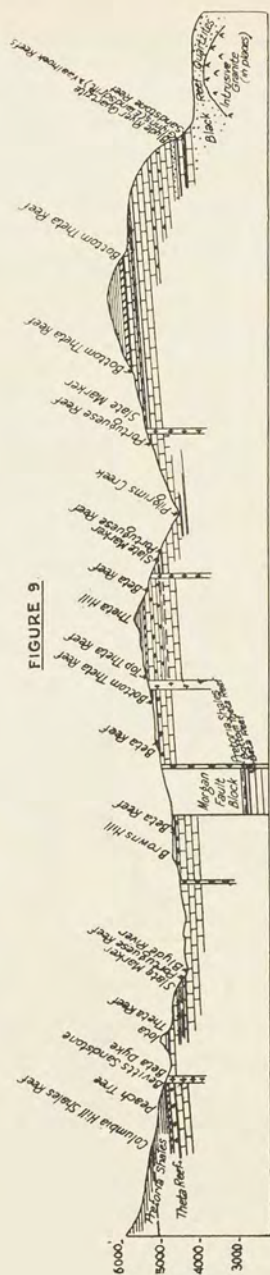


FIGURE 9

— Idealised E-W Section across Pilgrims Rest Gold Fields, to show relative positions of Ore bodies —

GOLD

Dividends, interest on and redemption of debentures and loans, and the Government's vendor share of profits may be looked upon as the net profit earned by the mine, and the balance of revenue, including taxation paid, as the cost. Applying this somewhat drastic classification, it would appear that the net profit in 1928 was £10,199,668, as shown in the following table, and the total cost £31,806,073, or 21s. 1d. per ton. If a further allowance be made for Union and Provincial taxation in the shape of income tax and companies tax, amounting approximately to £1,600,000 or 1s. 1d. per ton, the cost works out at 20s. 0d. per ton.

The following table shows the distribution of revenue under these various heads for the period 1912-28:—

Year.	Dividends.	Interest on and Redemption of Debentures. *	Interest on and Repayment of Loans (Approx.) *	Government's Share of Profits less Amounts Credited to Taxation. †	Net Profits.		Value of Recovery per Ton.	Balance of Recovery (Cost) per Ton.
					Total.	Per Ton Treated		
	£	£	£	£	£	s. d.	s. d.	s. d.
1912 ...	7,960,396	600,000	800,000	154,515	9,514,911	7 5	28 10	21 5
1913 ...	8,205,201	775,000	665,000	165,015	9,810,216	7 8	27 9	20 1
1914 ...	8,077,137	815,000	131,000	185,966	9,209,103	7 2	26 6	19 4
1915 ...	7,520,068	959,000	250,000	198,437	8,927,505	6 4	26 3	19 11
1916 ...	7,098,667	868,000	249,000	194,618	8,410,285	5 11	26 8	20 9
1917 ...	6,558,989	687,000	438,000	353,146	8,037,135	5 11	27 1	21 2
1918 ...	5,204,776	806,000	343,000	461,091	6,814,867	5 6	27 11	22 5
1919 ...	6,007,614	596,245	68,295	712,177	7,384,331	6 2	31 9	25 7
1920 ...	8,275,709	758,243	244,606	944,013	10,222,571	8 6	36 9	28 3
1921 ...	7,163,938	619,269	173,166	900,127	8,856,500	7 7	35 10	28 3
1922 ...	5,627,458	516,635	323,308	758,624	7,226,025	7 5	32 0	24 7
1923 ...	8,459,823	827,866	300,824	1,096,925	10,785,438	8 1	30 3	22 2
1924 ...	9,557,657	509,428	282,565	1,456,603	11,806,253	8 3	30 6	22 3
1925 ...	8,164,182	564,717	170,874	1,521,433	10,421,206	7 3	27 7	20 4
1926 ...	8,245,858	1,117,895	135,197	1,829,540	11,328,490	7 7	27 7	20 0
1927 ...	7,987,524	788,000	80,600	1,667,435	10,523,559	7 2	28 0	20 10
1928 ...	7,980,093	522,232	50,029	1,647,314	10,199,668	6 9	27 10	21 1

* Not including redemptions or repayments covered by new issues.

† The amounts include Bewaarplaatsen moneys received by the Government and freehold owners.

CHIEF HEADS OF EXPENDITURE

The following figures indicate the fluctuations in the percentage of the value of the output of Witwatersrand gold mines which is expended on salaries, wages, and stores:—

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

Year.	Value of Gold Produced.	Expended on Salaries and Wages.	Expended on Stores.	Total Expended on Salaries, Wages, and Stores.	Percentage of Value of Gold Produced.
	£	£	£	£	%
1912 ...	36,909,200	13,557,340	9,753,751	23,311,091	63.2
1913 ...	35,628,828	12,877,762	10,128,800	23,006,562	64.6
1914 ...	34,064,403	11,939,804	9,808,480	21,748,284	63.8
1915 ...	37,200,568	13,013,452	10,434,963	23,448,415	63.0
1916 ...	38,038,008	13,732,483	11,787,597	25,520,080	67.1
1917 ...	36,935,139	13,613,571	12,189,128	25,802,699	69.9
1918 ...	34,776,014	14,061,293	12,569,906	26,631,199	76.6
1919 ...	38,168,826*	14,569,860	12,740,174	27,310,034	71.6
1920 ...	44,407,544*	16,876,142	13,814,659	30,690,801	69.1
1921 ...	41,993,399*	16,122,430	13,940,188	30,062,618	71.6
1922 ...	31,334,125*	10,936,244	10,638,351	21,574,595	68.9
1923 ...	40,446,239*	12,740,731	12,886,025	25,626,756	63.4
1924 ...	43,495,614*	13,256,864	13,250,185	26,507,049	60.9
1925 ...	39,596,401	13,310,397	13,214,820	26,525,217	67.0
1926 ...	40,978,750	13,594,604	13,381,409	26,976,013	65.8
1927 ...	41,207,230	14,004,988	13,953,382	27,958,370	67.8
1928 ...	42,005,741	14,567,237	14,154,480	28,721,717	68.4

* Including premium on gold.

NOTE.—The above figures for expenditure are for producing and non-producing mines together. The expenditure on non-producing mines in 1928, was £33,035 on salaries and wages and £56,345 on stores, or a total of £89,380, and if this amount is deducted, the percentage of expenditure on producing mines only of the value of gold produced comes out at 68.2 per cent.

SCALE OF OPERATIONS AND PRODUCTION

The Witwatersrand is unique because of the scale on which its mining operations are carried on. With the exception of one year when a strike was in progress the amount of rock hoisted from 1910 to 1928 varied from 26,708,573 to 36,732,387 tons per annum, and the total rock that has been hoisted to date is about 750 million tons. Of this quantity 631 million tons have been milled, and the average gold return per ton is 6.976 dwt. 9,178 tons of gold have been produced valued at £935,618,789 besides 977 tons of silver and 31,149 ounces of osmiridium. The area of ore-body mined and developed is about 98 square miles, which is that of a great city. The total length of shafts, haulage drives and other major development is 4,500 miles, that is the length of a tunnel from Capetown to Cairo and more than double the total mileage of streets in Greater London. The greatest vertical depth below the earth's surface to which man has excavated is the bottom of the Turf Shaft in the Village Deep mine, 7,638 feet from the surface. About 150,000 people are lowered and hoisted in and out of the mines every working day. The winding engines that do this and hoist the ore develop 225,000 horse-power, and the aggregate length of their winding cables is 140 miles. About 5,000 rock

drills are in constant use and the total footage drilled per year is no less than 20,000 miles. Twenty thousand tons of explosives are used per year with 33 million detonators and 39,000 miles of fuse.

The mines pay their 216,000 employes, white and native, £14,500,000 in wages per annum and besides this they feed the natives 60,000 tons of mealie (maize) meal and 3,250 tons of beans per annum, in addition to which the natives consume 500 tons of fish and a herd of about 60,000 cattle, besides minor items of diet, such as salt, sugar, etc.

The Witwatersrand produces just over half of the world's output of gold. In the succeeding table statistics of production are given for the years 1887 to 1928.

VALUE OF THE MINERALS PRODUCED FROM THE GOLD ORES OF THE WITWATERSRAND MINING DISTRICT.

Year.	GOLD.		SILVER.		OSMIRIDIUM.		DIAMONDS.		IRON PYRITES.		Total Value of all Minerals £
	Fine Ounces	Value at £4-24/73 per Fine Ounce, £	Fine Ounces.	Value. £	Ounces.	Value. £	Metric Carats.	Value. £	Tons.	Value. £	
1887	19,080	81,047									
1888	171,789	729,713									
1889	306,167	1,300,515									
	34,607*	147,001									
1890	408,569	1,735,491									
1891	601,810	2,556,826									
1892	1,011,743	4,297,611									
1893	1,221,171	5,187,205									
1894	1,581,590	6,718,167									
1895	1,811,172	7,693,370									
1896	1,832,001	7,781,846	2,500,000	275,000							88,615,495
1897	2,511,094	10,666,449									
1898	3,563,294	15,135,911									
1899	3,430,424	14,371,515									
1900	339,355	1,441,488									
1901	258,032	1,096,050									
1902	1,695,309	7,200,790									
1903	2,862,141	12,157,602	346,393	38,424	—	—	—	—	—	—	12,196,026
1904	3,645,700	15,485,949	411,162	46,827	—	—	—	—	—	—	15,532,776

ESTIMATED.

FUTURE OF THE RAND

Many estimates of the future life of the Rand and its probable output have been made in the past, and up to the present they have all been found to have fallen short of the accomplished facts. This does not mean of course that the field is inexhaustible, or that future outputs will continue to out-do our present expectations. There are factors used in estimating the life of the mines such as the depths to which mining can be carried on, and the minimum gold content at which ore can be worked at a profit, which are vastly different and more favourable to-day than they were thirty years ago, and these may continue to change for the better in the future. That is, it may be possible to mine somewhat deeper than 7,500 feet, and in certain circumstances to make a profit on ore under 4 dwt. per ton in value. On the other hand, the natural conditions under which mining must take place are becoming increasingly difficult.

There is a fairly large area of possible ore-body on the East Rand of whose value and depth from the surface, we have some, though not very accurate knowledge. Our present knowledge would indicate that a large tonnage can be expected from there. There is a far larger area south of the central Rand which probably carries much payable ore, but at depths that appear at present to be too great to mine. Finally, there is a narrow strip of country over 100 miles in length stretching from the Rand to Klerksdorp and beyond, which may contain large ore-bodies. The Witwatersrand rocks outcrop over portions of this ground and in places conglomerates occur in it that carry small bodies of payable ore. There is reason to believe that conglomerates of the Witwatersrand System exist over all of this strip, though they are for the most part covered by later sediments. It seems probable also that there are large blocks of payable reef in this belt, at any rate in the area that lies close to the present western limit of developed mines. The structure in this neighbourhood is, however, very complicated and to prove such ore-bodies will be both difficult and costly.

The latest estimate by the Government Mining Engineer on the future of the Witwatersrand gives a probable available reserve of 320 million tons of payable ore for the 32 large mines on the Rand, and a possible further tonnage of 180 million tons.

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CHAPTER V.

GOLD (*cont.*), PLATINUM, SILVER

HEIDELBERG

The gold ores that have been mined at Nigel and the Sub-Nigel mines in the Heidelberg district are essentially a part of the Witwatersrand field and lie on its south-eastern border. (Figure 8.) They correspond in geological character to the ores described in the previous chapter, and are mined and treated by the same type of organization in the same manner. The production from this mine area is practically that given under Heidelberg in the table on page 154.

KLERKSDORP

Areas of Witwatersrand rocks occur in and near the village of Klerksdorp, 103 miles south-west of Johannesburg. Among the outcrops of Witwatersrand rocks are many conglomerates and some of these carry small blocks of payable ore. Gold has been produced from these ore-bodies, and from conglomerates in the Black Reef series, since the early days of the Witwatersrand.

At one time there was great prospecting activity in this district, and in the year 1895 seventeen gold mining companies were registered with a nominal capital of £3,235,000. To-day the Afrikander mine, with a 20-stamp battery, is the only property of any size in operation. The production from this district is given in the table on page 154. The first recorded production was 6,790 fine ounces in 1890, and since then some gold has come from there every year except during three years, at the time of the Anglo Boer War. The maximum production was 71,776 ounces in 1895 and in 1928 it was 21,175 ounces.

Gold has been produced in Klerksdorp area at points east and south-east of Klerksdorp village, on Rietkuil and Elandslaagte farms ten miles to the west, and at Buffelsdoorn and Machavie mines that lie thirteen and twenty miles respectively to the north-east of the village.

Most of the gold won from Klerksdorp has come from conglomerates of the Witwatersrand system. A few diamonds were also obtained from these reefs. Although attempts have been made to correlate these reefs with those occurring in the same system on the Rand, their respective horizons in the system have not been satisfactorily proven. The Buffelsdoorn mine on Buffelsdoorn and

the Afrikander mine on Rietkuil, appear to be working conglomerate ore-bodies that lie near the horizon of the Government reef on the Rand. A number of small mines or prospects on the Klerksdorp commonage have developed reefs, that from the coarseness of the pebbles and general appearance of the accompanying strata are believed to lie near the top of the Witwatersrand system.

At Buffelsdoorn mining is done on one or more bands of conglomerate lying within 4 feet of each other. They vary individually from zero to 30 inches in thickness. The reefs occur in a band of quartzite from 100 to 200 feet in thickness, overlying a broad band of shale and underlying Ventersdorp lavas. Fifty feet in section below the mined reefs there is a large pebbled band of conglomerate, 2 to 3 feet thick, which carries little or no gold values. A band of tillite outcropping to the west indicates that the horizon of the mined reefs may be that of the Government reef of the Rand. The reefs that have been worked in Witwatersrand beds near Klerksdorp are mostly big pebbled conglomerates lying in grits and quartzites.

In addition gold occurs in the conglomerates of the Black Reef series, which directly overlie the Ventersdorp lavas in a long line of outcrops east of the main Witwatersrand belt. Osmiridium has also been produced from the Black Reef. The Machavie, Eastleigh and other small mines were opened on this horizon. The Black Reef conglomerates carry pebbles up to egg size and have a large content of pyrite. The reef zone consists of bands of conglomerate interbedded with quartzite and in places with shale. The whole reef zone varies in width from 2 to about 6 feet and is in most places directly underlain by Ventersdorp lava. Gold is said to occur in well defined shoots.

Methods of mining in Klerksdorp resemble the procedure followed on the shallower workings of the Witwatersrand, and ore reduction is based on Rand practice.

PILGRIMS REST

The Pilgrims Rest goldfield lies in the Eastern Transvaal about 200 miles east-north-east of Johannesburg. It is situated west of and above the Drakensberg escarpment in mountain country of great scenic beauty. The field overlooks the Low Veld to the east. (Figure 8.)

Gold ores occur within an area that is about forty miles north and south by seven miles east and west. The principal gold producers are interbedded reefs, that is tabular ore-bodies lying roughly parallel to the bedding

planes of sediments of the Transvaal system. They dip for the most part at an angle of 4 degrees west. In places also vertical or steeply dipping lodes cut through the sediments and the underlying granites. These are referred to as leaders.

Gold was discovered here in 1872 and from that time to the present some £15,000,000 worth has been produced from this field.

THE ORE-BODIES

The reefs consist of partly replaced country rock, quartz, pyrite or its derivative, limonite and gold; copper minerals accompanying the gold in a few places only, and in relatively small amounts. Sphalerite, galena and bismuthinite have been recorded, but are exceedingly rare. Gold is in finely divided form and is seldom visible in hand specimens. It is closely associated with pyrite or limonite. In most of the ore that has been mined the pyrite is completely oxidized to limonite.

Interbedded Reefs

The bedded ore-bodies occur in very thin sheets. Their average thickness is from 15 inches to 3 feet ranging in a few places to 8 feet while their areal extent is measured in acres. (Plate XXII.)

Bedded reefs tend to occur within certain definite geological zones and have been named according to the zone within which they are supposed to lie. The ore-bodies are not, however, continuous along any given horizon nor do ore-bodies in the same zone lie along exactly the same beds in different localities. The principal ore-bodies in the district are the Glynn's reef at Sabie together with the Elandsdrift and Vaalhoek reefs, all of which are believed to lie in the same geological zone; and the Portuguese, Beta and Theta reefs at Pilgrims Rest. All of these occur in the Dolomite series. Another important ore-body is the Columbia Hill shales, a combination of bedded and cross reefs that occurs in shales a few hundred feet above the base of the Pretoria series. The Sandstone reef in the Black Reef series at Sabie, and the Betty reef in the shales at the base of the dolomite series have produced gold, but in smaller amount. The location of the principal interbedded ore-bodies in the geological section is shown in the diagram (Figure 9).

There is a very marked inclination for the gold and gangue minerals of any particular reef to form along certain

beds in preference to those lying directly over or under them. Because of this the structure of each individual ore-body tends to be characteristic. In certain cases an ore-body consists of two bands of quartz replacing beds of shale with a more or less altered band of dolomite and chert between. In such cases the bulk of the gold is found consistently in either the upper or lower of the two bands, the other being practically barren. Such a system may vary laterally by replacement of the central band to a solid quartz, pyrite reef. Reefs of this type are the Elandsdrift reef with the bulk of the gold in the top band, the reef at Horseshoe Creek mine with gold in the basal band, the Portuguese reef at Ponies Kranz mine, the Beta reef and the top Theta in parts of the Clewer mine. In other cases there is one band of quartz, with the country rock on either side replaced, for a foot or more, by pyrite. The bottom Theta reef at Pilgrims is an example of this kind, the gold occurring for the most part in the country rock. In the Portuguese reef on North Jubilee mine, again, the ore-body consists of country rock replaced by pyrite, and quartz is present in relatively small amounts only.

Cross Reefs or Leaders.

Ore-bodies of steep dip may extend vertically through the granite for several hundred feet. Where such ore-bodies cut across the sediments, however, they tend to be strongly developed at certain horizons and to be apparently missing or very small in others. This gives rise in places to lath shaped or irregular ore-bodies of greater lateral than vertical extent. The principal ore-bodies of this type are the "Blow" at Elandsdrift, the Thelma reefs at Vaalhoek, the Dientje, Mali Dyke, and Rietfontein lodes.

The greatest bulk of all ore mined in this district is thoroughly oxidized with change of the pyrite to limonite or its entire removal. This is accompanied by leaching of the carbonate content of the dolomites, the residue being soft masses of silt or clay stained with manganese. The process is accompanied in places by the deposition of secondary quartz and of gold. The movement of gold does not appear to have been of sufficient magnitude to affect the position of the principal primary ore-bodies.

ORIGIN OF THE ORES.

The occurrence of gold deposits in the Transvaal system near Pilgrims Rest and not elsewhere is accounted for by

the presence of a granite batholith which is intruded into the Black Reef and dolomite series to the south of Sabie. Gold bearing solutions associated with the granite magma moved upwards through fissures in the sediments. These trend for the most part north to north by east, and nearly east-west. From the fissures the solutions spread laterally along the bedding planes of the sediments. Certain restricted geological horizons were favoured by the gold-bearing solutions and these were selected from a sedimentary section that is hundreds of feet in thickness. Within these horizons one narrow bed is in many places ore-bearing, while those just above and below it are barren. Ore-bodies were formed in the vertical fissures in places, in others one can observe a vertical ore-body passing laterally into an interbedded one. The relations between bedded ore-bodies and vertical fissures indicate also, that, in certain cases, the latter acted as barriers to solutions moving along the bedding, and thus determined the areal distribution of the gold at that locality.

In the process of surface weathering the nearly flat lying interbedded ore-bodies offer relatively porous channels to the movement of atmospheric water, and thus tend to become base levels for moving oxygenated water. Dolomites overlying such ore-bodies are therefore apt to become leached and altered to "soft rock" more rapidly than where an ore-body is not present.

MINING METHODS.

The principal mines occur around the village of Pilgrims Rest where at the present time eighteen small mines are being worked under one management. At Sabie, twenty miles to the south, there is a number of mines in operation, and one at Elandsdrift about 12 miles farther south. Small mines are being worked on Dientje, Ledouphine and Lisbon farms to the north-east of Pilgrims Rest and in the high country around Mount Anderson to the south-west. Two mines of fair size, Vaalhoek and Frankfort to the North of Pilgrims, were worked at one time. Vaalhoek has produced much gold and was only recently shut down.

The principal ore-bodies lie nearly flat and outcrop for the most part in mountainous country. The majority of them are thoroughly oxidized and the dolomites adjacent to them have been leached of their carbonate content and converted into soft rocks of no strength. Such leaching gives rise to slumping and the elimination of outcrops.

The main principle on which prospecting is done, is the known persistence with which gold occurs at certain horizons. Such horizons are followed along their strike and exposed by trenching or adits into the hill sides. Where slumping has taken place, pits are sunk, or long trenches are opened across the general direction of the strike.

The flat lying ore-bodies are developed by cross-cut adits into the hills or incline shafts down the dip of the reef, and from them tunnels are driven at intervals along the strike of the ore-body. Shallow vertical shafts are put down in places for ventilation purposes and to deal with isolated ore-bodies. Where portions of the flat reef bodies have slumped through surface weathering and slipped down hill, adits are if possible driven to the bottom of the ore-body and the ore stoped out above. The ore is usually composed of limonitic and fairly soft material so that much of it can be picked out. The ore-body is in many cases not much over one foot in width and the narrowest stopes worked on South African mines are probably in this field. For example, at Brown's Hill, one of the mines under the control of the Transvaal Gold Mining Estates, a large area of nearly flat reef was mined at an average stope width of approximately 12 to 15 inches. In some cases the stope width was as low as 8 to 9 inches. The reef was hard and interbedded between solid dolomite beds and had to be drilled and blasted. In certain workings with narrow reefs resuing is resorted to and in many instances the ore is bagged at the face. Where the stopes are very narrow roads high enough to accommodate a two-wheeled truck are driven at convenient intervals from a central haulage way, and the ore lashed out to them from the stopes in places with scrapers. Trammings is done by hand either to the surface or to main haulage ways where winches are used to haul to the surface if the grade requires it.

Because of the treacherous nature of the hanging in the leached dolomite areas, much money and labour is spent on the support of excavations. Sheets of diabase are interbedded with the dolomites in many places, and where the rocks are thoroughly altered these are changed to red clay which expand and even flow on becoming wet. Pillars and cribs are used to support the roof of stopes and square set timber or stulls in the haulages. Because of the conditions outlined, timbers have to be constantly renewed in certain sections of the mines. Where resuing is adopted the stope is supported by the broken waste.

The dolomites contain enormous reservoirs of water in places and with a rainfall of from 40 to 80 inches mine drainage is a serious problem in this field. At Glynn's Lydenburg Ltd., the number of gallons removed from the mine, during the past two financial years, has averaged 2,200,000 gallons per 24 hours. During the latter year the average rose to nearly $2\frac{1}{2}$ million gallons per 24 hours, equal to 60 tons of water for every ton of ore raised. The peculiarity of underground drainage in dolomite is that large quantities of water exist in these rocks adjacent to, but isolated from, each other. When such reservoirs are broken into in the course of mining operations serious floods result which in many cases stop mining operations for months at a time in that neighbourhood. The mines are all comparatively shallow and mine ventilation is not on the whole a serious problem.

The ore is crushed in stamp batteries or tube mills, and the gold caught on amalgam plates and treated further in cyanide plants on the same general plan as that used on the Rand, but on a much smaller scale and with modifications to suit local conditions. Some trouble is experienced in recovering the gold in parts of the field because of small percentages of copper that occur in the ore.

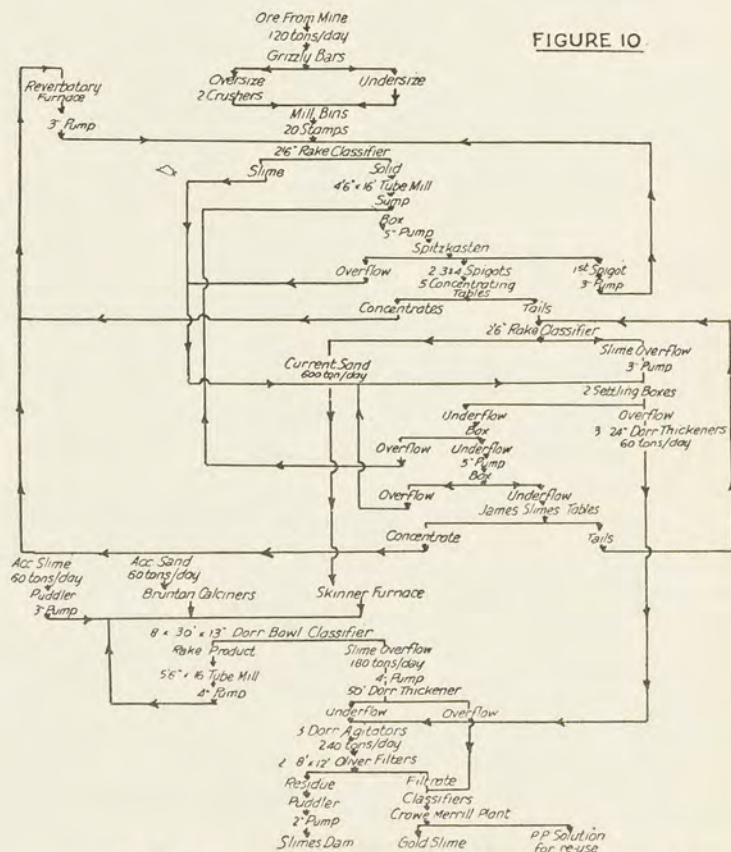
The larger number of mines belong to the Transvaal Gold Mining Estates with headquarters at Pilgrims Rest. At that place the ore is hauled by electric trains and other means to a central mill and there treated. 141,400 tons of ore at a yield of 6.55 dwt. per ton were treated at this mill and in smaller mills at the Vaalhoek and Elandsdrift mines belonging to the same company during the last financial year. Glynn's Lydenburg Ltd. mine at Sabie crushed 75,300 tons and produced 25,064 ounces of gold during the 12 months ended July 31, 1929. A few other and much smaller concerns are also in operation.

Details of production for this district are given in the table on page 154.

BARBERTON

The village of Barberton is about 185 miles east by north of Johannesburg. It is 328 miles by rail from that place, and 136 miles from the port of Lourenço Marques in Portuguese territory. (Figure 8.) Gold has been won from the country surrounding Barberton for 48 years, see page 154.

Barberton lies in a belt of very rugged mountains trending north-east and south-west between the valleys of



Flow Sheet - New Consort Gold Mines Ltd. - Barberton Dist

the Kaap and Komati Rivers. Twenty miles or more to the north-west is the edge of the Drakensberg escarpment with elevations of from 5,000 to 6,128 feet. The village of Barberton is 2,734 feet above sea-level while near-by peaks rise to 5,350 feet. The country becomes more rugged southward and less so towards the north-east.

THE ORE-BODIES

The deposits of gold occur partly in the ancient quartzites and shales of the Moodies' series, and partly in the schists and carbonate rocks of the Jamestown series of the Swaziland system. They occur in the proximity of the margins of the great bodies of granite intrusive in the Swaziland system; most of the mines so far worked are situated within the contact aureoles of the Crocodile Poort and De Kaap granite *massifs*. It should be stated that the intrusion of the granite was accompanied by powerful earth movements, and it is along the fracture and shear planes thereby produced that most of the mineralization took place. There are also unimportant occurrences in the granite near their contact with the sediments.

Three main types of gold deposits have been worked, namely,

1. Replacement or impregnation deposits of more or less regular outline, connected with well-defined fissures, faults or zones or crushing.
2. Contact metasomatic deposits in which gold is accompanied by arsenopyrite.
3. True "reefs" or fissure veins.

In all three types of occurrence the workable ore occurs in shoots which are often extremely rich at the surface, but tend rapidly to become poor at depth.

1. Examples of the first type are provided by the famous Sheba Mine, the most prolific producer on these fields, which between 1886 and 1918 yielded 952,715 ounces of gold valued at £4,046,876. It consists of four main groups of workings known respectively as the Old or Golden Quarry and the Zwartkopjes, Intombi and Insimbi Mines. They all present much the same features. Gold, in association with pyrite occurring as delicate stringers or in well formed crystals, is found in zones of impregnation or replacement in quartzitic or graphitic slates underlying steeply dipping bars of banded or ferruginous chert. The zones of impregnation are connected with planes of fracture occupied by clay or carbonate matter.

The main Sheba or Golden Quarry Shoot measured 120 feet at its widest point and was 300 feet long. It conformed roughly to the stratification of the surrounding rocks, and was worked for 1,200 feet in the direction of the dip. Near the surface it yielded ore averaging 10 ounces of gold to the ton, but values fell off very considerably at depth.

2. This type of deposit is illustrated by the Consort and Maid of De Kaap mines, situated near Noordkaap Siding. In the former the ore occurs, according to Hall, in a series of disconnected lenses in metamorphosed carbonaceous shale, now represented by tourmaline-rich silicified graphitic hornstone. The ore minerals, which are intimately intergrown with the silicates, include, in addition to gold, arsenopyrite, pyrrhotite, pyrite, chalcopyrite and antimonite. In the Maid of De Kaap mine, which presents similar features, there was found in 1925 a patch of ore containing 12 per cent. of gold.

3. Examples of this type of deposit are furnished by the Alpine, Shebang, Durham and Barbrook mines, all of which are on vertical or steeply inclined quartz veins. Such veins have hitherto proved relatively unimportant as a source of gold production.

MINING METHODS⁵

The mining methods employed naturally depend on the nature of the ore-body being exploited. The mountainous nature of the country and the fact that the outcrops of the ore deposits usually occur on the sides of the valleys and in some cases along the ridges and crests of the mountains have caused most of the development operations in the district to be undertaken by means of adits at various horizons below the outcrop; the adits either being put in as cross-cuts to intersect the ore-bodies or as drives along the strike of the deposit. Winzes, raises and cross-cuts are then used for further development as well as the blocking out of ore reserves, and to provide the necessary faces from which to open out stopes.

The ore-bodies usually dip at a steep angle, hanging and footwalls are in most places not sound and a fair amount of timbering is necessary to render the workings safe. The "true" reef or fissure vein type of deposit is

⁵ The sections on mining methods and the extraction of gold were contributed by W. J. Gau, Consulting Engineer to the South African Townships Mining & Finance Corporation, Johannesburg.

usually of narrow width with well defined walls, and in such deposits mining conditions are comparatively easy. In the replacement or impregnated deposits such as at the Sheba, New Bonanza and Sofala mines large tonnages were obtained at the commencement by open quarrying, with consequent low mining costs. This was followed by underground operations with increased costs, where the ore-bodies dipped into the mountains. At the New Consort mines, De Kaap Section, which is situated on the mountain side, the steeply inclined lenticular ore-shoots, or lenses, which dip with the slopes of the mountain, are opened up by means of adit cross-cuts. Where the shoots are of sufficient size they are developed by means of winzes and raises and the ore stoped out in the usual way.

In many instances especially in the Queen Consort section of the same ore deposit, the detached ore lenses which are from four to five feet wide are of considerable lateral extent, but of limited extent on the dip. Here the ore as it is met with is stoped out for development on orthodox lines and stoping operations usually give indications which lead to the discovery of the next lens. In the Queen Consort section, which is located at the foot of the mountain, development is undertaken by means of incline shafts and winzes. The main shafts have reached a depth of over 600 feet and are put down on the footwall of the ore-body which dips at 45 degrees. A well-defined and persistent quartz bar, which occurs on the hanging wall of the section, in contact with a chistolite slate, is used as an indicator for the location of new ore-bodies, both laterally as well as on the dip. In locating new lenses a considerable amount of dead work is necessary on account of their detached nature and this is particularly true in locating the continuation of the shoots at depth.

EXTRACTION OF THE GOLD

Where the ore is free milling extraction of the gold by the usual methods of amalgamation and cyaniding give a high percentage of recovery. In deposits of the contact, replacement or impregnated types the ore may be of an extremely refractory nature, and difficulties are experienced in obtaining a satisfactory and economic extraction. An example of this is the ore of the New Consort mine which contains, apart from high gold values, a considerable percentage of arsenopyrites besides pyrrhotite, chalcopyrite and a small amount of antimonite. The gold in this ore is, as a rule, not visible. To obtain a proper extraction

the ore requires a complex treatment as the following details of the treatment plant now in course of completion at the New Consort will indicate. (Figure 10.)

Briefly the treatment is one of fine grinding the ore, concentration, roasting and re-grinding of the concentrates which are returned to the tube mill circuit, the fine grinding of sands after calcination in Skinner and Brunton furnaces (fired by producer gas) and the combined treatment by cyanide of the slimes together with re-ground calcined sands in the slimes treatment plant consisting of Dorr agitators and Oliver filters. The final extraction takes place in a Crowe-Merrill plant. An extraction of 80% to 90% is expected, the capacity of the plant being 6,000 tons per month—3,000 tons of current ore and 3,000 tons of accumulated sands and slimes.

It is of interest to note that a considerable amount of arsenic is recovered in chambers and flues from the roasting of the table concentrates in the reverberatory furnace.

At the New Consort and other mines a considerable proportion of the power used for driving air compressors for jackhammer drills and for operating the mill, is supplied by hydro-electric plants of modern design. An up-to-date steam power plant at Noordkaap Station also supplies electrical power to the New Consort mines.

Costs

The costs of mining are in general quite low in this district. In most cases water is drained by gravity through adits driven below the deposits. A remarkable example of low working costs is furnished by the operations of the Sofala Gold Mining Company in 1927. The mine crushed 44,286 tons of ore valued at 1.75 dwt. per ton, mining costs were 2.78 shillings per ton, ore reduction costs 2.82 shillings per ton and general charges 2½d. per ton, total 5s. 10d. per ton with a profit of 1s. 6d. per ton. The mine paid a dividend of 9% for the year, but has since shut down, owing to exhaustion of payable milling grade ore at 1.4 dwt. per ton. Average costs for the field are, of course, much higher than this. Details of production for the Barberton District are given in the table on page 154.

OTHER GOLD DEPOSITS

MALMANI

On this field, centred about Ottoshoop in the western Transvaal, a considerable amount of work has been done

GOLD, PLATINUM, SILVER

on a system of fissure veins intersecting the dolomite, which here dips at angles ranging from 5 to 15 degrees to the east-north-east. The veins were discovered in 1875 and production appears to have reached its zenith during the next three or four years. The veins have a prevalent north-north-west-south-south-east trend and are either vertical or dip steeply to the west-south-west. They range in thickness from a foot to nearly 100 feet. They consist of quartz or of brecciated dolomite cemented by quartz, or of brecciated quartz cemented by carbonates. Narrow quartz stringers often parallel the main body of the reefs on either side.

The ore minerals are gold, which occurs in nuggety masses, specks and scales, chalcopyrite and bornite and their oxidation products malachite and azurite, pyrite and limonite pseudomorphous after it. The association of gold and copper is characteristic of this field. In some of the veins galena, zinc-blende and secondary manganese oxides are also present. A number of the veins were rich in gold at the surface, but on the whole they proved very poor and patchy. Mining operations were, moreover, hampered by the great volumes of water struck about 150 feet from the surface. The field has in consequence acquired a very unfortunate reputation, and is at present lying fallow.

Veins of auriferous quartz in the Pretoria series were worked at one time on the farms Blaauwbank 104, and Koesterfontein 108, situated in the western part of the Krugersdorp district.

The production from Malmani or Ottoshoop is given in the table on page 154.

WAAIKRAAL

An interesting deposit of gold occurring as an original constituent of an igneous rock was discovered in 1925 on the farm Waaikraal 205, in the Rustenburg district and forty-two miles west-north-west of Pretoria.

Metallic gold, and the gold telluride krennerite, occur as original constituents of a sill of pyroxenite—soda bearing—quartz-gabbro. The sill which is 3 feet 6 inches to 14 feet thick is intrusive into quartzites, calcareous shales and ironstone of the upper portion of the Pretoria series. The sedimentary rocks have been greatly altered as a result of the intrusion. Gold grains up to 2.5 mm. in diameter occur with grains of limonite after pyrite or enclosed in fresh grains of augite, and plagioclase. The

highest gold values invariably occur in the central part of the sill. The ore-body extends to a length of strike of about 300 feet. Values were comparatively high in the thicker portions of the sill. About 5,250 oz. of fine gold were produced from here in the years 1928 and 1929.

MURCHISON RANGE

The Murchison Range lies in the Low Veld of the eastern Transvaal about 230 miles as the crow flies north-east of Johannesburg and 200 miles by rail from the port of Lourenço Marques. The climate is unhealthy and has retarded development of the gold deposits lying in this field and in some other portions of the Pietersburg District.

The deposits of the Murchison Range, which from time to time have attracted a good deal of attention, occur in two well defined parallel belts some three or four miles apart, corresponding with two conspicuous lines of hills that constitute the central portion of the range. The gold occurrences of the two belts are very similar except in one important particular, and that is, that those of the northern belt almost everywhere contain notable amounts of antimony in the form of stibnite and its oxidation products senarmonite and stibiconite, while that element is absent in the deposits of the southern belt. The northern belt is on this account referred to as the Antimony Belt to distinguish it from the southern or Spitzkop Belt.

According to Mellor there are three main types of deposit. They are:—

1. Lenticular veins, usually composed of coarsely crystalline quartz, or quartz with calcite and other carbonates, showing no schistose structure; the veins, while generally conforming to the foliation of the surrounding rocks, often cut across it. The most striking characteristic of this class of "reefs" is their rapid and extreme variation in thickness both along the strike and when followed in depth, as well as their want of continuity in both these directions. Gold is often visible to the naked eye and may or may not be accompanied by stibnite in slender prisms or in masses or bunches of considerable size. Pyrite is also generally present.
2. Mineralized zones in chlorite, talc or quartzose schists. These consist of innumerable lenses and thin sheets of quartz, often exhibiting a schistose structure and usually associated with calcite or

dolomite intimately interleaved with the schists and following their foliation planes. Gold is always accompanied in these deposits by pyrite and in those of the Northern Belt stibnite is also present. The pyrite and stibnite are frequently fractured and sometimes present evidence of having been drawn or rolled out. It is quite clear, therefore, that the mineralization preceded the general metamorphism of the area. We have here good examples of dynamo-metamorphosed gold deposits.

3. "Black or Burnt Reefs," apparently highly pyritic replacement deposits in banded ferruginous quartz schists, with numerous bands of ferruginous material and sometimes composed entirely of iron oxides. No examples of a deposit of this type carrying stibnite has so far been found.

All three types of deposit are vertical or steeply inclined. A considerable amount of work has been done on them. Results on the whole have been very disappointing, due partly to the undoubted patchiness of the deposits so far as gold is concerned, and the difficulties of extracting the antimonial ores.

THE LETABA GOLDFIELD

In the Letaba goldfield situated in the "Low Country" some distance north of the Murchison Range, auriferous quartz or quartz-carbonate veins have been worked with indifferent success at the Birthday and Ellerton mines.

MISCELLANEOUS DEPOSITS.

Auriferous gold quartz veins occur in the Swaziland beds at Eersteling, the scene of the first gold discovery in the Transvaal, and other localities to the south and south-east of Pietersburg.

Similar veins in the Old Granite were at one time worked on the Haenertsburg and Woodbush goldfields.

They are also of common occurrence in the Swaziland beds of Natal and Zululand, but so far no really important deposits of this type have been discovered in the territories named.

At Abelskop and Goudplaats in the Harts River Valley, western Transvaal, gold occurs in quartz stringers in strongly plicated banded ironstones associated with chlorite schist.

At Madibi in the Mafeking division of the Cape Province gold, partly in the form of gold telluride, occurs in association with pyrite and pyrrhotite in quartz veins

**PRODUCTION OF GOLD IN THE UNION OF SOUTH AFRICA, CLASSIFIED UNDER MINING DISTRICTS, TOGETHER
WITH THE WORLD'S PRODUCTION AND THE PERCENTAGE PRODUCED IN SOUTH AFRICA.
FROM EARLIEST AVAILABLE RECORDS.**

Year.	Witwaters- rand. Ounces.	Heidel- berg. Fine Ounces.	Klerks- dorp. Fine Ounces.	Otto- hoop. Fine Ounces.	Pre- toria. Fine Ounces.	Barber- ton. Fine Ounces.	Pilgrims Rest. Fine Ounces.	Pieters- burg. Fine Ounces.	Totals for Trans- vaal. Fine Ounces.	Cape. Fine Ounces.	Orange Free State. Fine Ounces.	Natal. Fine Ounces.	Union of South Africa. Fine Ounces.	World's Produc- tion. Fine Ounces.	Union's Percent- age of World's Produc- tion.
1433-1883	—	—	—	—	—	—	—	—	—	—	—	—	—	348,564,866	
1884	—	—	—	—	—	—	—	—	2,376	—	—	—	—	4,925,155	
1885	—	—	—	—	—	—	—	—	1,414	—	—	—	—	5,121,141	
1886	—	—	—	—	—	—	—	—	8,171	—	—	—	—	5,135,673	
1887	19,080	—	—	—	20,800	—	—	—	39,880	—	—	—	—	5,116,833	
1888	171,789	—	—	—	38,657	—	—	—	227,749	—	—	—	—	5,137,859	
1889	306,167	—	—	—	27,438	—	—	—	350,909	—	—	—	—	5,973,759	
	34,607	—	—	—	—	—	—	—	2,497	—	—	—	—	5,827,380	
1890	408,569	—	—	—	—	15,444	—	9,349	440,152	—	—	—	—	6,102,842	
1891	601,810	—	—	—	—	52,844	—	18,972	688,439	—	—	—	—	7,077,276	
1892	1,011,743	57	4,471	1,032	—	31,580	—	12,036	1,069,058	—	—	—	—	7,618,811	
1893	1,221,171	14	12,780	898	—	35,345	—	15,356	1,290,218	—	—	—	—	8,764,362	
1894	1,581,500	40,572	62,821	442	6	70,806	—	40,792	1,895,000	—	—	—	—	9,615,190	
1895	1,811,172	33,211	71,776	708	258	51,621	—	41,131	2,017,443	137	—	127	2,017,707	9,783,914	
1896	1,832,001	21,024	29,453	35	740	108,511	—	35,055	2,025,510	125	—	38	2,025,673	11,420,068	
1897	2,311,094	19,893	61,476	—	117	105,778	—	41,974	2,743,518	73	—	37	2,743,698	13,377,806	
1898	3,463,294	34,946	48,358	—	691	79,304	—	96,733	3,823,367	104	—	15	3,823,468	14,837,775	
1899	3,430,424	45,333	19,571	—	unknown	61,338	—	78,017	3,637,713	150	—	56	3,637,889	12,315,135	
1900	339,555	—	—	—	—	3,400	—	6,006	348,761	115	—	12	348,888	12,625,527	
1901	258,032	—	—	—	—	275	—	—	258,307	70	—	142	258,519		

13.6

3.06

These
years
and
prior
to
1884
1884
2,497

1902	1,695,209	6,966	—	15,769	1,717,944	24	—	78	1,718,046	14,321,360
1903	2,862,141	27,055	2,253	79,937	2,971,416	11	—	—	2,971,427	15,747,378
1904	3,645,700	31,969	3,124	87,170	3,770,963	33	—	—	3,770,996	16,804,372
1905	4,729,657	55,411	14,401	108,118	4,908,087	86	—	108	4,908,281	18,396,451
1906	5,668,645	70,800	11,336	142,012	5,792,823	263	—	73	5,793,159	19,471,080
1907	6,221,068	81,200	8,696	351	6,450,740	562	—	878	6,452,180	19,977,200
1908	6,780,757	81,892	12,314	634	7,056,266	392	—	412	7,057,100	21,422,244
1909	7,043,359	80,259	17,122	1,369	7,295,108	131	—	1,593	7,296,832	21,965,111
1910	7,228,448	76,842	18,533	267	7,427,108	91	—	4,184	7,531,386	22,022,180
1911	7,910,034	72,005	30,002	1,412	8,249,461	73	—	1,706	8,251,240	22,348,313
1912	8,731,970	84,806	31,644	953	9,107,512	38	—	1,212	9,108,792	22,549,335
1913	8,424,951	82,843	33,498	420	8,798,336	30	—	347	8,798,713	22,249,596
1914	8,034,389	79,115	37,389	77	8,394,322	40	—	1,706	8,396,068	21,240,416
1915	8,771,920	79,999	32,273	—	9,093,392	48	—	2,461	9,096,411	22,674,568
1916	8,968,270	90,438	19,639	206	9,296,618	31	—	315	9,296,964	21,970,788
1917	8,705,413	107,829	11,681	481	9,018,684	15	—	290	9,018,389	20,389,546
1918	8,194,944	76,288	5,878	315	8,418,292	2	—	85	8,418,379	18,556,920
1919	8,109,050	72,292	241	108	8,331,294	8	—	349	8,331,651	17,605,037
1920	7,949,084	73,854	144	—	8,168,226	19	—	210	8,168,455	16,205,029
1921	7,930,700	69,314	404	—	8,128,681	2	—	27	8,128,710	15,974,962
1922	6,797,772	63,286	3,216	—	7,009,767	6	—	85	7,009,858	15,451,945
1923	8,915,815	70,086	10,513	—	9,148,771	10	—	292	9,149,073	17,790,597
1924	9,320,276	76,210	17,751	—	9,574,918	3	—	119	9,575,040	19,031,001
1925	9,341,049	84,797	18,170	—	9,597,573	—	—	19	9,597,592	18,053,915
1926	9,656,778	115,989	19,750	—	9,954,762	—	—	—	9,954,762	19,400,000
1927	9,715,015	224,731	19,351	—	10,122,459	—	—	32	10,122,491	19,600,000
1928	9,899,895	263,472	21,175	—	10,354,157	—	59	48	10,354,264	19,500,000
Totals to date	220,263,244	8,762,331	—	—	229,025,575	5,162	59	20,322	229,031,118	1,021,456,776

* Or 34.0 per cent. during period since gold first produced in South Africa.

following crush zones and chlorite-biotite-schist and banded ironstone belonging to the Kraaipan series. Good values were obtained near the surface, but the deposits proved very patchy.

At the Denny Dalton and Dickson mines, situated in the Vryheid district of Natal, beds of auriferous conglomerate belonging to the Lower Pongola series (Swaziland system) were at one time worked. The Denny Dalton conglomerate contains a good deal of marcasite.

ALLUVIAL GOLD

Notwithstanding the very wide distribution of primary gold occurrences in the Union of South Africa and the stupendous denudation which that territory has undergone since Jurassic times, alluvial gold is surprisingly rare. Indeed, the only really important deposits so far discovered in South Africa are those of the Pilgrims Rest district. Here considerable amounts of the metal were recovered in the seventies of last century from the Pilgrims Creek and Blyde Valley, and the neighbourhood of MacMac and Spitzkop, where gold washing on a small scale is still in progress. The total value of the alluvial output to date is estimated at over £500,000. This is greatly in excess of the official returns which only date from 1902. Part of the gold was of the nature of eluvial gold, and fairly considerable quantities of eluvial gold have also been recovered from the deposits on Mount Anderson in the same district.

Alluvial and eluvial gold, in the form of nuggets and irregular grains, are also found on the Godwan River plateau particularly in the gulleys near the village of Kaapsche Hoop. The Peacock Nugget, weighing 178 ounces and named after its finder, was picked up here in 1912.

Alluvial gold has also been worked spasmodically on a small scale at Millwood near Knysna in the Cape Province. The source of the gold is believed to be the Table Mountain Sandstone, exposed near the alluvial workings.

PRODUCTION OF GOLD IN THE UNION.

Details of the production of gold from the various mining areas in the Union together with the total production from the Union of South Africa are given in the table (pages 154 and 155). To this has been added the figures for the world's production since 1493. These figures show at a glance how large a portion of the world's gold has been derived from the Witwatersrand field.

PLATINUM

HISTORICAL

In 1892 William Bettel proved that metals of the platinum group, both iridosmium and platinum, existed in the conglomerate gold ores of the Rand, but the first shipment of 23 ounces from this source was not made until 1920. Since then 31,149 ounces of osmiridium have been won from the ores of the Rand.

In June, 1923, platinum was discovered by Adolph Erasmus in a lode deposit in the Waterberg district of the Transvaal, but although good values were obtained from the ore-bodies their exploitation was not a financial success. Toward the end of 1924 Dr. H. Merensky traced alluvial platinum found in Steelpoort valley in the Lydenburg district to its source in pipes of dunite, and in the pyroxenitic norite band that is now known as the Merensky Reef. (Plate XXIII.) During the following year he, with others, traced the amazingly extensive Merensky reef over many miles in the Potgietersrust and Rustenburg districts. The first output of platinum metals from the dunite and Merensky reefs was 10,545 ounces in 1926. The production in 1928 was more than double that amount, and as the difficulties connected with the extraction of the metals from the ores are overcome, the output will doubtless increase to a very much higher figure.



Plate XXIII.—One of the first excavations on the Merensky reef, Lydenburg district. From left to right: H. Merensky, W. F. H. Dudgeon, unknown, G. Carleton Jones, J. J. Buschau, W. E. Turvey.

[Photo, G. Carleton Jones.]

DISTRIBUTION.

The platinum deposits so far discovered in Southern Africa lie in a belt between longitudes 26° and $30^{\circ} 40'$ E. The southernmost is at Insiswa in the Cape Province on or about latitude 31° S. and the northernmost at Kilo in the Belgian Congo, latitude 2° N. Those that are at present of economic importance occur on the Witwatersrand and in the Bushveld Complex of the Transvaal, see figure 11.

Outside of alluvial and eluvial gravels platinum occurs, according to Wagner, in deposits ranging from the Waterberg lode deposits of Cretaceous age to those occurring in the Swaziland system. Those of economic importance are the deposits of the Bushveld Igneous Complex which belong to the geological era of the Transvaal system. In addition platinum metals are found in the Black Reef series of the same system and the gold reefs of the Witwatersrand system.

MINERALOGY

The metals of the platinum group can be divided into two sections: palladium, ruthenium and rhodium with specific gravities ranging from 12.16 to 12.44; and platinum, iridium and osmium with specific gravities from 21.50 to 22.47. Their hardness ranges from platinum 4.3 and palladium 4.8 to ruthenium and iridium 6.5 and osmiridium 7. They all have very high melting points and are extremely resistant to acids. Platinum and palladium are malleable and ductile, while iridium is hard and brittle. In general they combine readily as alloys. Of the six, platinum, palladium and iridium are the more important commercially. Platinum and palladium are used extensively in the jewellery trade, in dentistry and in the electrical and chemical industries. Iridium in small amounts is alloyed with platinum and palladium for increasing their hardness. Its alloy with osmiridium is extremely hard and is extensively used for fountain pen points and in other ways.

In the Waterberg lode deposits platinum occurs as a natural alloy with palladium and gold in zonally banded grains.

In the deposits of the Bushveld complex native platinum occurs alloyed with from 6 to 21 per cent. of iron and smaller quantities of other platinoid metals, as well as gold, copper, nickel and cobalt. In addition platinum is found as the platinum (arsenide) sperrylite PtAs_2 , as the sulph-arsenide, cooperite, Pt(AsS)_2 , and palladium occurs combined with antimony in stibio-palladinite Pd_2Sb .

In the dunite deposits of the Transvaal these sulphides are encountered for the most part below water level where they make up to 25 per cent. of the platinum content. It is probable also that a whole series of solid solutions of the platinum metals occur in these ores. In the Potgietersrust deposits of the Bushveld complex it has been found that some of the platinum and palladium exists in solid solution in the sulphides, pentlandite, chalcopyrite and pyrrhotite.

ALLUVIAL DEPOSITS

Eluvial and alluvial deposits occur along the outcrops of, and in streams draining, the lode deposits of the Waterberg and the deposits of the Bushveld norite, but none of them has so far proved of commercial importance.

LODE DEPOSITS OF THE WATERBERG DISTRICT

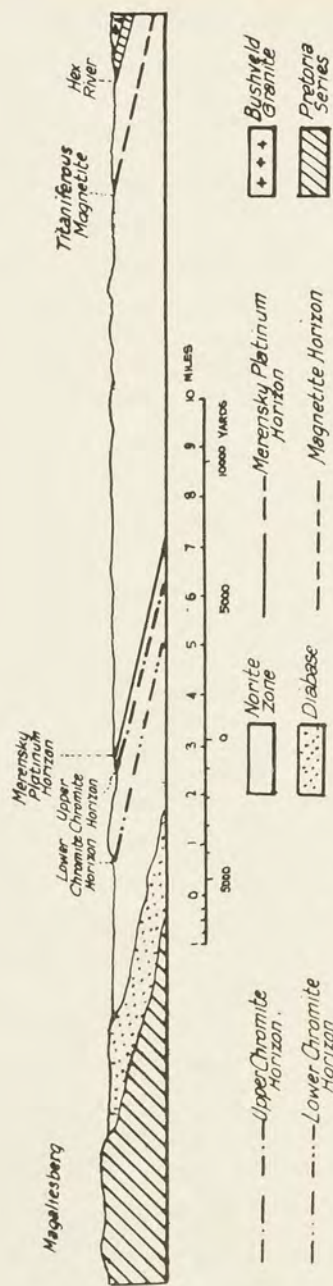
These deposits which are situated 8 miles WNW of Naboomspruit in the central Transvaal, were discovered in June, 1923. They occur as brecciated quartz lodes occupying faults of post-Karoo age.

Platinum occurs in irregular patches some of which are of extremely high value. It is associated with quartz chalcedony, specularite, sericite, chromiferous chlorite, and kaolin. Several lodes were discovered, but only two of these were workable. These were opened to a depth of 100 feet over a length of 3,000 feet. The workable ore was found in small irregular patches which were so erratic in their distribution that it was found impossible to exploit them at a profit. Operations were suspended in 1926.

DEPOSITS OF THE BUSHVELD IGNEOUS COMPLEX

The Bushveld Igneous Complex occupies an area 280 by 150 miles in the central Transvaal. The outside rim of the complex is occupied by norites and allied basic rocks and the central portion by granites, granophyres, felsites, basalts and tufts. The norite is up to two and a half miles in thickness and outcrops over widths of five to twelve miles. It has been intruded in the form of a basin shaped sheet or lopolith into the upper part of the Pretoria series, and dips at from 5 to 50 degrees from all sides towards the central part of the complex.

The norite sheet is composed of layers that lie one over the other and vary in their composition. In certain parts



Section across the Norite Zone of the Bushveld Complex near Rustenburg, showing relative position of Chromite, Magnetite and Merensky Platinum Horizon

After P.A. Wagner.

FIGURE 11.

of the norite body these layers exhibit pseudo-stratification, in which the rocks are almost as regularly banded as in a sedimentary series. (Figure 11.)

From the base upwards the norite has been differentiated into:—

1. Basal or chilled phase of diabasic norite.
2. Transitional zone of basic bronzitite norite and pyroxenite.
3. Differentiated zone of narrow pseudo-stratified bands of norite, pyroxenite norite, pseudo-porphyrritic diallage norite, harzburgite, chromitite and anorthosite.
4. Main belt of undifferentiated norite. Near the top of this are bands of titaniferous iron forming a huge deposit of that metal as well as anorthosite and pyroxenite norite.
5. Diallage norite with leucocratic types near the top.

Although platinum has been found at other horizons in the norite, all deposits of platinum metals of economic importance so far discovered occur in the differentiated zone. Platinum deposits occur in a variety of ways within the norite body. According to their mode of origin and their position in the norite body Wagner has classified them in the following table:—

CLASSIFICATION OF THE PLATINUM DEPOSITS OF THE NORITE ZONE OF THE BUSHVELD IGNEOUS COMPLEX.

C. Pneumatotectic deposits formed by indirect segregation from the parent norite magma.

- (8) Deposits in acid quartz-bearing differentiates of the norite magma.
- (7) Deposits of the Blaauwbank type in which the ore-bearer is quartz-bearing anorthositic norite.
- (6) Deposits of the Steelport Park type in which the ore-bearer is a medium-grained feldspar-rich spotted norite.
- (5) Deposits of the Minsk's claims type, Lydenburg district, in which the ore-bearer is a rather coarse-grained feldspar-rich diallage norite.
- (4) Deposits of the Merensky horizon type occurring above and below the main horizon in the Lydenburg district.
- (3) Deposits of the Merensky horizon type as developed in the Rustenburg, Pretoria, Lydenburg, Pietersburg and Potgietersrust districts; the ore-bearers are pseudo-porphyrific pyroxenitic diallage-norite, feldspathic pyroxenite, feldspathic harzburgite and chromitite.
- (2) Deposits of the Tweefontein type (Potgietersrust district) in which the ore-bearer is a fine-grained pyroxenitic diallage-norite merging into coarse-grained feldspathic bronzitite and bronzitite.
- (1) Deposits of the Vlaktefontein type (Rustenburg district) in which the ore-bearer is bronzitite.

(a) In the upper part of the norite zone.

III. Deposits in which platinum is associated with magmatic nickel-copper-iron sulphides in norite, pyroxenite and harzburgite.

(b) In the lower part of the norite zone.

II. Chromitite deposits.

I. Olivine-dunite deposits, Iron-rich olivine-dunite deposits, Hortonolite-dunite deposits.

A. Orthotectic deposits formed by direct segregation from the parent norite magma.

B. Contact-metamorphic deposits in altered dolomite or sheared banded ironstone directly underlying platinum-bearing norite or pyroxenite.

GOLD, PLATINUM, SILVER

Of the deposits listed in the table those that have proved of economic importance are olivine-dunite deposits (AI), deposits in the Merensky horizon (AIII b3), other deposits of about the same type and horizon (AIII b2) and contact metasomatic deposits B. They only are described below.

OLIVINE-DUNITE

Platinum occurs in pipes or in irregular segregations of hortonolite-dunite through a range of 2,000 feet vertically in the norite body, but the only occurrences of economic importance, so far discovered, are between the lower and upper chromite horizons near the base of the norite sheet. Hortonolite is an olivine in which the proportions of iron and magnesium orthosilicates vary from 1 : 1 to 2 : 1.

At both Onverwacht and Mooihoek mines in the Lydenburg district the hortonolite-dunite occurs in the form of a parsnip shaped pipe lying near the centre of a pipe of ordinary olivine-dunite with which occurs also pegmatitic diallage. The pipes are intruded across the pseudo-stratification of the norite and dip at angles of 70 to 80 degrees to the horizon. The platinum bearing hortonite-dunite pipes are from 2,000 to 4,000 square feet in horizontal cross section and one of them has been developed to a depth of 950 feet. Good values of platinum have been found in these pipes, the average in one case being 6 and 7 dwt. of platinum metals to the ton. At Driekop mine in the same district platinum occurs throughout a pipe of olivine-dunite, but is more richly concentrated in relatively small segregations, veins and schlieren of iron-rich olivine lying in the olivine-dunite. The horizontal cross section is about 5,000 feet and it has been followed down for 480 feet. The average grade of ore sent to the mill from this mine is from 3 to 4 dwt.

The origin of the dunite pipes is ascribed to the segregation from a basic magma, free of alkalies, of a fraction poor in silica and alumina and rich in iron and magnesium. The basic portion because of its greater fluidity remained liquid longer and was intruded across the earlier crystallized portion. The iron rich portion accompanied by platinum crystallized in the centre of the pipes.

THE MERENSKY HORIZON

In these deposits platinum is associated with the sulphides of nickel, iron and copper, pentlandite, pyrrhotite and chalcopyrite.

The Merensky horizon is a name given to a band from 6 to 35 feet thick, of pyroxenitic diallage norite which over vast stretches of country is found lying at about the same horizon in the upper part of the differentiated zone of the main norite sheet. This band which is underlain by a light coloured spotted anorthosite has been found outcropping at intervals for 180 miles in the Rustenburg and Pretoria districts, 100 miles in Lydenburg and Pietersburg districts and some forty miles in the Potgietersrust district. The average rock is made up of the minerals bronzite, diallage, labradorite-bytownite, brown mica, hornblende, chromite, magnetite and the sulphide pentlandite, pyrrhotite and chalcopyrite.

In the Rustenburg occurrences and in parts of the Lydenburg district the horizon is composite in character, and is made up of bands of the type rock together with feldspathic hartzburgite, feldspathic pyroxenite and chromitite. The rock variations are made up of the same minerals as the main type, but in different proportions. The platinum of the Merensky horizon which occurs associated with sulphides is everywhere accompanied by palladium. In Rustenburg and Lydenburg the proportions vary from 12 to 25 per cent. of palladium and 66 to 78 per cent. of platinum. In Potgietersrust it varies from 44 to a maximum of 62 per cent. of palladium and from 38 to 55 platinum. With these are other platinum metals, and also gold and silver, but the latter are in smaller proportions.

Where the Merensky reef is thin platinum occurs all through the body of the band, where it is very thick it tends to occur near the hanging wall. When differentiated into bands enrichment occurs along certain bands or in definite portions and combinations of bands. Thus in parts of the Rustenburg district most of the platinum is concentrated in a chrome band and in a band of feldspathic pyroxenite adjacent to it, both of which underlie the Merensky reef proper. Under these conditions the platinum-rich zone embraces only the lower portion of the Merensky reef proper. In the Lydenburg district the average platinum content of the reef as tested over a wide area is about 2 dwt. per ton. In Rustenburg it averages from 5 to 7 dwt. over a stopping width of 30 inches, through stretches measuring from 5,000 to 18,000 feet along the strike and several hundred down the dip.

In Potgietersrust district the norite sheet cuts across the formations and comes in contact with progressively

lower geological units from the Pretoria series to the Older Granite. In places it has thrust tongues into the sediments and incorporated masses of sediments into its own mass.

The main Potgietersrust horizon, which has been traced for a distance of over twenty miles in the portion of the norite zone trending north-northwestward from Potgietersrust, is probably the equivalent of the Merensky horizon. It consists, speaking generally, of a thick sheet of pseudo-porphyrific diallage-norite enclosing big lenticular bodies of coarse grained feldspathic bronzitite. Only the latter rock and a coarse grained hornblende norite into which it passes locally carry notable amounts of platinum. On Sandsloot 276 the entire thickness of the horizon amounting here to 143 feet is occupied by these rocks. The uppermost 80 feet averages over 3 dwt. of platinum per ton.

CONTACT METASOMATIC DEPOSITS

On the adjoining farm Vaalkop 256 and Zwartfontein 121 the ore horizon has the same characteristics, except that the pseudo-porphyrific norite is only locally developed. The ore horizon is here directly underlain by dolomite or more correctly calcium- and magnesium-silicate rocks derived from dolomite. These rocks for a considerable distance from the igneous contact have suffered impregnation with platinum and sulphides, so that here we have magnetic deposits in juxtaposition with contact metasomatic deposits. In trench No. 1 on Vaalkop, where the composite ore-body has been carefully sampled it averages 7 dwt. over a width, measured horizontally, of 100 feet. On Zwartfontein 121, equally promising values have been obtained.

Situated a few miles to the south-east is the remarkable contact metasomatic deposit on the farm Tweefontein 1033. Here platinum in the form of the rare mineral sperrylite, occurs in shear zones in banded ironstone flooring the Bushveld complex and in sheared intrusions of pegmatite in the banded ironstone. The sperrylite is found in perfect crystals up to 1.7 cm. across, that is of a size hitherto unheard of.

The zone of oxidation extends to below the present water level in most cases, thus the average depth of water level in the Potgietersrust fields is 20 feet and the average depth of oxidation 60 feet. Near Rustenburg the water level is from 40 to 60 feet, and oxidation extends from 70 to 140 feet. Platinum occurs in the oxidized zone usually in the form of sperrylite and cooperite, and partly in colloform and nuggety grains, which from their form and

structure are believed to have been formed from colloidal solutions. It has been definitely proved that platinum and palladium have been leached by atmospheric waters out of the Merensky horizon on a big scale in places, and that they have been re-deposited in the underlying anorthositic norite.

Wagner suggests that the presence of mineralizers, principally sulphur, helped to bring about the extreme differentiation seen in sections of the Merensky horizon between rocks rich in calcium and aluminium on the one hand, and in magnesium and iron on the other. The minute fractions of the metals nickel, iron, copper and platinum collected with the sulphur in the magnesium iron-rich portion. The metals were probably in solution in the sulphur in a gaseous state. There is no evidence of gravitative control. In segregating the heavier residues seem in fact to have moved upward and to have crystallized toward the top of the bands of pseudo-stratified rock, suggesting that matte droplets bearing platinum might have been carried up in the final crystallizing of the magma to the highest plane in which solids could exist under the conditions holding at the time. There is evidence to show that crystallization of the banded portion of the norite sheet as a whole took place from the base upward.

The other occurrences of platinum-bearing rock within the norite, as given in the table (page 162), have not, up to the present, proved of economic importance.

METHODS OF MINING

Three mines are being worked in dunite. These are Onverwacht, Mooihoek and Driekop in the Lydenburg district. The dunite pipes were mined open-cast to about 80 feet. Below this they were developed by sinking a shaft well away from the pipe and cross-cutting to it at intervals of 100 feet. From there cross-cut levels were opened and connected with winzes. The ore is being mined by the shrinkage stoping method at Mooihoek and Driekop. At Onverwacht concrete mats are built across the pipe at vertical intervals of 50 feet. From here the ore is extracted by overhead stoping with simultaneous filling with waste. Ore passes are kept open through the column of waste and the ore sent down them to levels below, from which it is hauled to the surface.

The combined cost of mining Mooihoek and Driekop with one-third of the ground coming from Mooihoek and two-thirds from Driekop is 6s. 7d. per ton, not including development.

In the composite lenses of the Potgietersrust fields stopping widths of 20 to 50 feet obtain in ore-bodies dipping from 50 to 90 degrees. Here top slicing with simultaneous waste filling is practised.

The deposits of the Merensky horizon in the Rustenburg district with sheet-like ore-bodies, dipping from 9 to 25 degrees, resemble the ore-bodies on the Rand in their shape and regularity, and are being mined in the same general way. Pneumatic picks are being used to break down the oxidized ore without the use of explosives. In these deposits there is a rich concentration of platinum in bands about 12 inches wide, and different forms of resuing are being practised. In this operation a slice of either the foot or hanging wall is first removed, and the ore can then be mined cleanly.

EXTRACTION OF PLATINUM¹

The different classes of ores from which platinum is being extracted in the Transvaal each require somewhat different metallurgical treatment.

In the dunite ores found in the Lydenburg district, and being worked at Mooihoek, Driekop and Onverwacht, the platinum is generally in metallic grains comparatively finely divided and generally associated with chromite.

The value of the ore treated is at present from 4.5 to 5.0 dwt. per ton of 2,000 lb. The usual methods of crushing and classification are practised, and the platinum is extracted mainly by gravity concentration, the rich concentrate being amalgamated by a modification of the Zachert process or repeatedly re-dressed on concentrating tables for the separation of the metallic platinum. A high value metallic product is finally obtained which finds a ready sale to refiners. A small proportion of the recovery at Maandagshoek (Plate XXIV) is obtained by the flotation process. The total recovery is from 85 to 88 per cent. of the ore value.

Pyroxenite ores of the Merensky Reef are being worked profitably in the Potgietersrust and Rustenburg districts. In the oxidized ore the platinum is present mainly as arsenide and sulph-arsenide; free gold is also present. In the sulphide ore the platinum metals are closely associated with base metal sulphides. Chromite is present in large quantity. In this class of ore the percentage of palladium present in the total platinoids is an important economic factor. In the Rustenburg district the percentage of

¹ This section was prepared by A. King, Consulting Metallurgist to the New Consolidated Goldfields Ltd.

palladium in the ore milled is from 10 to 15 per cent., but at Potgietersrust it is about 50 per cent. of the total platinoids. Both gravity and flotation concentration methods are being or will be used in conjunction. It has been shown that not only sulphide ore but also oxidized ore can be treated with fair success. A readily realizable product is separated from oxidized ore by gravity concentration, and further extraction is made by flotation. From oxidized ores (Rustenburg) it appears that some 45 to 50 per cent. of the ore value will be recovered in marketable form by gravity and concentration, and a further 15 per cent. by flotation. From sulphide ore a total recovery of 80 to 85 per cent. is anticipated.

Concentrate Treatment.

Where the platinum exists in a clean metallic form excellent recoveries can be made by the amalgamation method or by careful redressing of the concentrate.

With a concentrate from a sulphide ore from which copper, nickel and iron sulphides have been separated along with the platinum metals, smelting to a matte may be adopted and the matte subjected to acid or other treatment by means of which the platinum metals may be separated in form suitable for final refining.

Another method which has been developed locally and will shortly be in operation on a working scale depends upon converting the platinum metals into chlorides. The concentrate is roasted and then subjected to chlorine gas in a closed furnace at a temperature of about 550° C. The resulting salts of copper, nickel and the platinum metals are dissolved out with acidulated water and precipitated separately from the solution.

PLATINUM METALS OF THE WITWATERSRAND.

Osmiridium occurs in minute quantities in the Witwatersrand reef, and is won from concentrates on the corduroy tables as explained on page 112. It occurs also in the Black Reef conglomerates, and has been produced from these conglomerates in small quantities at Klerksdorp and elsewhere.

Osmiridium is a mineral composed of a number of metals of the platinum group and gold in varying proportions. The following shows the range of composition for osmiridium from the Witwatersrand. Osmium is the predominant metal, followed by iridium.



Plate XXIV.—Reduction plant on Maandagshoek where the ores from Mooihoek and Drickop are treated.

[Photo, G. Carleton Jones.

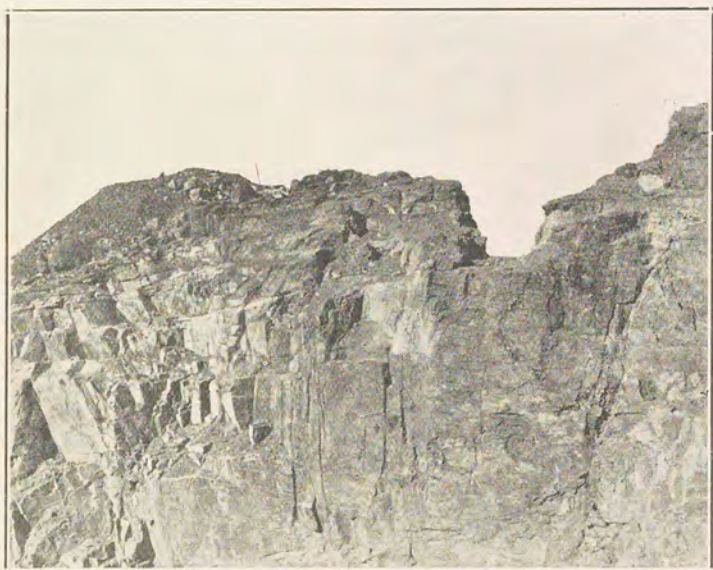


Plate XXV.—Outcrop of cupriferous norite dyke, intruded into granite gneiss, Tweefontein mine, Namaqualand.

[Photo, A. W. Rogers.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

PERCENTAGES.

	Maximum.	Minimum.	Average of Witwatersrand Output 1928.
Osmium	23.75	39.98	33.82
Iridium	21.12	37.08	28.88
Ruthenium and Rhodium	10.52	15.84	12.83
Platinum	4.57	14.99	10.05
Gold	—	8.66	1.16
Undetermined ...			13.26
		Total	100.00

An area in the heart of the Far East Rand consisting of the New Modderfontein, Modderfontein B. Modderfontein Deep, Government Gold Mining Areas and Brakpan Mines produces from 0.3 to one ounce of osmiridium per 1,000 tons of ore milled. The production from mines adjacent to those referred to is very much smaller. On six mines west of Boksburg the production varies from 0.1 to 0.25 oz. per 1,000 tons crushed.

PRODUCTION OF PLATINUM METALS.

The following table gives the production of osmiridium from the Witwatersrand from 1921 to the present. In 1920, 23 oz. were shipped and realised £15 16s. 6d. per ounce.

Year.	Produced oz.	oz.	Realized.	
			Value. £	Value per oz. £
1921	509.580	509.580	6,801	13.346
1922	761.563	761.563	13,165	17.287
1923	3,100.595	1,764.183	43,528	24.673
1924	5,763.500	4,107.481	102,886	25.048
1925	5,490.401	6,055.250	170,995	28.239
1926	6,228.129	6,359.781	96,734	15.210
1927	5,472.524	5,653.180	58,137	10.284
1928	5,670.637	5,990.983	86,921	14.509
Total	32,996.929	31,202.001	579,167	18.562

The outputs of platinum derived from ores of the Bushveld Complex from the first year of production in 1926 to the end of 1928 are as follows:—

Year.	Production. oz.	Sales.	
		Fine oz.	Value. £
1926	10,545.203	4,951.347	93,307
1927	19,570.234	10,431.397	144,191
1928	23,662.908	17,827.628	241,110

FUTURE OF PLATINUM PRODUCTION.

The production of osmiridium from the gold ores of the Rand depends obviously on the tonnage of gold ore mined, and whether future methods of gold concentration will permit of the winning of osmiridium in the same proportion as at present. The production will probably not greatly exceed the present output of 5,000 to 6,000 ounces per year.

The total amounts of the platinum metals that are actually present in the Merensky horizon is large enough to supply the world's needs for an indefinite period. A certain proportion of these exist in proportions too small to be considered payable in any circumstances. Great sections of this ore-body, however, carry an average of from 4 to 5 dwt. of the platinum metals to the ton, that is it can be exploited at a profit under present conditions. The cost of producing an ounce of platinum from such ore is estimated at from £6 to £8 at the present time. If the platinum industry continues to develop on a paying basis for a number of years, the cost per ounce will probably decrease. If platinum prices were stabilized by an international selling organisation, or otherwise, at a figure above that quoted, the platinum mining industry in South Africa would develop steadily even if on a small scale. Its expansion thereafter would depend on improvements in mining and in the extraction of the metals, and in the discovery of new uses for the platinum metals in the arts and industry.

SILVER

The only silver at present being recovered in the Union of South Africa is that contained in the gold bullion produced by the Witwatersrand and other gold mines. The total output from this source up to the end of 1928 was 23,453,063 fine ounces. The Rand gold, as already stated, contains an average of about ten per cent. of silver, the proportion of silver to gold varying considerably in different parts of the gold field and in one and the same mine.

During the period 1922-5 considerable amounts of silver were produced at the Transvaal Silver Mine, the silver being contained in the work-lead sent abroad for refining (see section on page 216). This mine also produced a good deal of silver before the Anglo-Boer War.

Two other early producers of silver in the Transvaal were the Albert Silver Mine on the farm Roodepoortje 149, situated twenty miles north-east of Bronkhorstspuit, and the Willows Silver Mine on the farm The Willows 23, ten

miles east of Pretoria. At the Albert Mine, discovered in 1885, there was worked a well-defined vertical east and west replacement lode following a zone of fissuring in granite porphyry. A diabase dyke following the fissured zone forms a portion of the lode. The outcrop of the lode was marked by a conspicuous gossan 50 feet in width. The lode itself is up to 100 feet in width. The ore is confined to two fairly definite sheets. The principal ore mineral is argentiferous bornite. This is accompanied by chalcopyrite, tetrahedrite, chalcocite, cuprite, malachite, azurite, native copper and gold. The gangue consists of quartz, specularite and hematite accompanied by subordinate amounts of siderite. The bornite carried up to 1,600 ounces of silver to the ton, present partly in the metallic state in arborescent forms, and partly as the silver sulphide, argentite. The deposit was worked to a depth of 230 feet and produced a fair quantity of ore averaging 10 per cent. of copper and 40 ounces of silver to the ton.

The veins worked at The Willows Silver Mine lie in the shales and diabases separating the Daspoort and Magaliesberg quartzites of the Pretoria series. They are nearly vertical, and the main lode is a contact lode with a hanging wall of diabase and a footwall of shale. The principal ore mineral was argentiferous tetrahedrite associated with chalcopyrite, pyrite and secondary copper carbonates.

Beautiful azurite crystals were a feature of the oxidized ore. The gangue consists of magnesia-rich siderite containing notable amounts of manganese; at and near the surface it is oxidized to limonite and goethite.

Similar veins outcrop on the farms Boschkop 295 and Oudezwanskraal 537, which are similarly situated with regard to the quartzites of the Pretoria series. The vein on Oudezwanskraal contains, in addition to the minerals above named, notable amounts of arsenopyrite which affords a connecting link with the tin deposits of the Bushveld complex.

The production of silver in the Union to date amounts to over £3,500,000 in value and the figures in the following table indicate the output from 1911-1928:—

GOLD, PLATINUM, SILVER

Year.	Silver in Gold Bullion.		Silver in Base Metals.		Total.	
	Fine oz.	Value. £	Fine oz.	Value. £	Fine oz.	Value. £
1911	896,333	98,479	271	28	896,633	98,507
1912	966,333	119,106	52,680	5,268	1,019,013	124,374
1913	943,907	114,794	8,890	1,028	952,597	115,822
1914	890,782	102,471	—	—	890,782	102,471
1915	966,177	106,245	—	—	966,177	106,245
1916	968,904	106,308	31	3	968,935	106,311
1917	938,146	172,997	—	—	938,146	172,997
1918	877,522	187,608	—	—	877,522	187,608
1919	873,558	224,248	17,746	4,556	891,304	228,804
1920	861,363	238,311	31,230	7,560	892,593	245,871
1921	821,037	136,046	9,292	1,395	830,329	137,441
1922	736,634	113,989	379,042	57,438	1,115,676	171,427
1923	888,082	127,516	485,848	70,372	1,373,930	197,888
1924	933,847	142,670	463,096	69,800	1,396,943	212,470
1925	934,254	134,996	227,216	31,902	1,161,470	166,898
1926	981,333	126,580	—	—	981,333	126,580
1927	1,011,736	118,531	—	—	1,011,736	118,531
1928	1,031,376	124,064	—	—	1,031,376	124,064

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CHAPTER VI

BASE METALS: COPPER, IRON, TIN

Copper, iron and tin were mined and smelted in pre-European times in Southern Africa. Although copper and tin mining are well established industries in South Africa, we have not yet discovered very great deposits of the ores of these metals. The iron ores are just beginning to be developed, but they occur in such vast deposits that it is more than probable that they will at some future date be looked upon as our greatest mineral asset after coal.

COPPER

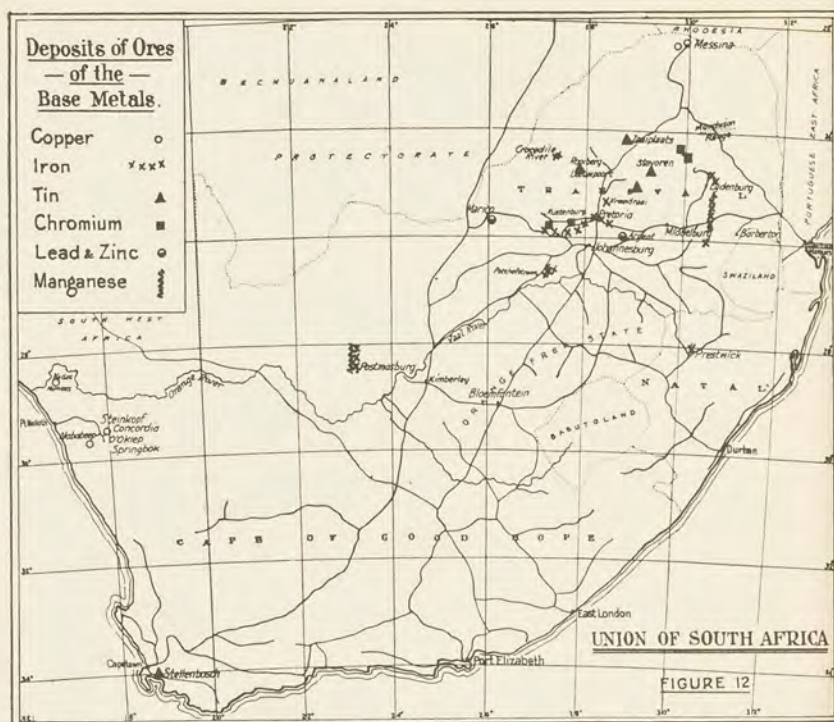
HISTORICAL

Copper was mined by the ancients on a large scale in the northern part of the Transvaal at a period that antedates the arrival of the white man by hundreds and perhaps thousands of years. It was the first metal to which the attention of Europeans was directed after the Dutch had established themselves at the Cape, and in 1685 Governor Simon van der Stel himself travelled up to the Orange River to investigate the source of copper ornaments brought to his settlement by the Hottentots. For a century and a half after that nothing was accomplished, and it was not until 1852 that copper ore was mined by Philips and King near Springbokfontein in Namaqualand. This was apparently the first metal mining done by Europeans in South Africa.

At least a dozen mines have contributed appreciably to the copper output of this field, but the most important have been those of O'okiep and Nababeep, belonging to the Cape Copper Company, and Tweefontein, owned by the Namaqua Copper Company. (Figure 12.) Each company owns smaller workings as well. The great decline in the price of copper, which commenced in 1918, led to the cessation of operations in the Namaqualand mines in April, 1919. Smelting operations were restarted towards the end of 1922. The copper that has been produced in Namaqualand from the first year for which records are available up to the end of 1928 is valued at £20,734,721.

At Messina, in the northern Transvaal, ancient miners prospected and mined over an area of six square miles. They worked the ores down to 80 feet from the surface and made excavations up to 30 feet in width. European prospecting has been going on there now for 29 years. Mining

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA



commenced in 1904, and the first concentrates were carried by ox wagon to the railway at Pietersburg, 170 miles away. Now the camp is connected by rail with Lourenco Marques, which is 430 miles away, and with Johannesburg.

In 1914 a small smelting plant was installed, and from then until 1928, 62,324·3 long tons of metallic copper were produced from 1,965,425 tons of ore.

Copper to the value of £5,352,593 was produced in the Transvaal from 1904 to the end of 1928, and the total value of copper produced in the Union to that date is £26,087,703.

Copper is being mined to-day in Namaqualand in the Cape Province, and at Messina in the Transvaal. Besides these, occurrences of copper have been prospected in the Uptington, Hay, Gordonia and Prieska districts of the Cape Province. At Insiswa Mountain, in East Griqualand, it is found in association with nickel and a little platinum, and it is reported from deposits in Natal.

NAMAQUALAND

This region, occupying a fairly considerable stretch of country in the north-west corner of the Cape Province, embraces two distinct areas, namely:—

(a) A northern region characterized by veins containing native copper and copper sulphides in a gangue of quartz, carbonates, feldspar, and chlorite. None of them is being worked at the present time. The Kodas and Numees Mines, situated in the mountainous country near the Orange River, yielded fair quantities of high-grade ore in the fifties of last century. Transport, however, offered insurmountable difficulties, and the mines were closed down after being exploited for some years. The former of these mines is said to contain considerable reserves of ore which will doubtless be worked as soon as the area is rendered more accessible by the construction of roads and railways.

(b) A southern region embracing an area of about 2,000 square miles in the middle of the division of Namaqualand which contains what are probably the best authenticated examples of copper deposits formed by direct magmatic segregation. They take the form of irregular dykes and intrusions of a genetically connected series of rocks, ranging from anorthosite and quartz-rock through mica-diorite and norite to hypersthenite, which contain as primary constituents varying amounts of chalcopyrite which may or may not be accompanied by bornite. In some of the bigger intrusions these minerals form irregular segregations of disseminated and massive sulphide ore. The economically important ore-bodies are confined to four main types of ore-bearer, namely:—

1. Hypersthenite, which forms the intrusion of the Nababeep and Carolusberg Mines.
2. Norite, which forms the intrusion at the Tweefontein Mine, and of the Jubilee Mine near Concordia.
3. Mica-diorite, the most widely distributed of these rocks which forms the intrusion at the O'okiep Mine.
4. Augite-diorite, which forms the ore-bearer of the Springbok Mine.

The country rock is gneissose granite, enclosing bands of sillimanite and sillimanite-garnet gneiss, which in the area containing the copper mines is disposed in the form of a great dome. The ore-bodies, as already indicated, are quite irregular in form and, as a rule, irregularly distributed through the ore-bearer in which they occur. The

ore-bodies are not related to later faults or fissures intersecting the ore-bearers. (Plate XXV.)

The accompanying sections through the Tweefontein Mine (Figures 13 and 14) give a good idea of the nature of the ore-bodies and of their relation to the ore-bearer. It should be stated that the gneiss in contact with the ore-bearers has in places been impregnated with sulphides which apparently replace the constituents of that rock. Such impregnations are, however, local and quite unimportant.

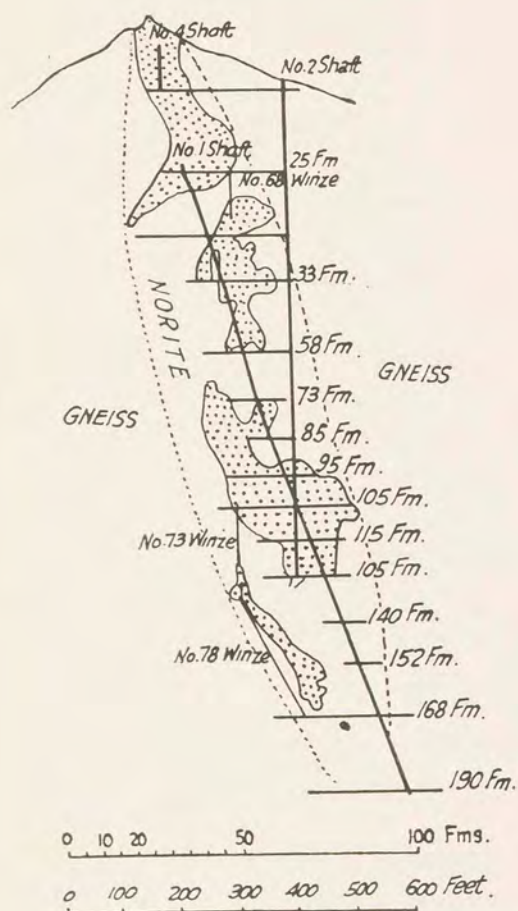
The mineralogy of the ore occurrences is very simple. Chalcopyrite and bornite are the chief ore minerals. Pyrrhotite is present in some of the deposits, but that mineral and bornite are, as elsewhere, mutually exclusive. Magnetite and hematite are generally present and sometimes abundant. Molybdenite is also often seen. The ores carry small amounts of gold which is recovered from the copper produced by electrolytic refining. In the oxidized zone the copper sulphides named are replaced by chalcocite, cuprite, tenorite, malachite, azurite, chrysocolla, and various sulphates, with which is associated the rare mineral cyanotrichile.

Upward of 340 separate intrusions of ore-bearer have been mapped. The more important occurrences referred to are those in the neighbourhood of:—

1. O'okiep, including the O'okiep, O'okiep East, Narrap and Narrap South mines.
2. Nababeep, in which the Nababeep mine is the most important.
3. Concordia, including the Tweefontein, Jubilee, Homeeb East and Homeeb West mines.
4. Carolusberg, including the Carolusberg, Carolusberg East and Koperberg mines.

Fair amounts of ore were also obtained from the Springbok mine near the village of that name, and from the Spektakel mine on the farm Spektakel, north-west of Naries.

By far the most important of these Namaqualand deposits was that worked for many years at the O'okiep Mine. This was a great irregular bulging dyke, 1,000 feet long and 380 feet wide, enclosing big xenoliths of gneissose granite. Vertically, the intrusion could only be followed to a depth of 630 feet where it apparently comes to an end. This deposit was exploited continuously from 1854 to 1915,



Projection on a vertical N-S plane of the
Tweefontein Copper Mine, Namaqualand.

After A. W. Rogers.

FIGURE 13

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

and produced well over 600,000 tons of ore and concentrate averaging 19.5 per cent. of copper. It was for many years the mainstay of the Cape Copper Company.

METHODS OF MINING AND TREATMENT

The occurrence of rich ore in great masses in the Namaqualand mines, in conjunction with the fact that the country rock has everywhere been found remarkably strong and reliable, has resulted in the formation of enormous stopes or chambers underground, some unsupported spaces being found as much as 75 or 80 feet in average diameter, with roofs from 70 to 120 feet high. Otherwise, the mining methods employed are not unusual.

The Cape Copper Company has relied entirely for its extraction on the process of "partial pyritic smelting," and so, also, for the most part, has the Namaqua Copper Company. The former company's smelters have a capacity of 8,000 to 9,000 tons per month, and those of the latter of about 3,000 tons. In both cases, a regulus of about 50 per cent. copper was produced and shipped to England, the quality of the metal being unusually pure. As adjuncts to the smelting plants, for preparation of the fines and by-products for the furnaces, the first company relied upon a sintering, and the other upon a briquetting plant, both of which proved entirely successful. In ordinary practice from 14 to 16 per cent. of Welsh coke was used in the furnace charges.

An Elmore concentration plant was installed at Concordia by the Namaqua Company, and proved fairly successful. The treatment by leaching of tailings dumps of poor oxidized ores, and of material too poor for smelting or unsuitable for the Elmore plant, was also tried with good effect.

MESSINA COPPER BELT

The mining area of Messina lies on latitude 22° 30' South, some 6 miles south of the Limpopo River, in the northern Transvaal. It is 430 miles by rail from Delagoa Bay and 380 miles from Johannesburg. With an elevation of 2,000 feet above tide, and a rainfall of 14 inches, the climate is hot for nine months of the year and cool for three. At the beginning of operations much trouble was occasioned by malaria, but to-day conditions are much improved. The Messina Transvaal Copper Company, Ltd., which operates the mines, mill and smelters, supplies its staff and the adjoining village with light, water and sanitary service.

THE ORE-BODIES

The copper ores occur in a well defined belt that trends ENE-WSW, and extends for fifteen miles from the farm Oostenryk 1421 to near the Limpopo River.

The copper belt ranges in width from 500 to 1,000 feet, and represents a zone of crushing, faulting and brecciation in the ancient gneissoid and granite rocks which occupy such wide areas in this part of the Transvaal.

Special reference must also be made to a persistent, steeply inclined dyke of altered dolerite, which follows a zone of fissure running roughly along the middle of the copper belt. This dyke, which can be traced for miles, is mineralized in places, and it is believed in some quarters that the solutions that gave rise to the copper deposits emanated from it or from the zone of fissuring which it occupies. The country rock is composed of hornblende-biotite-gneiss, with bodies of hornblende-schist and intrusions of a later red granite and still later grey aplite.

The ore minerals are bornite, chalcopyrite and chalcocite. In the upper levels of the mine to a depth of 200 feet chalcocite preponderated. Between 200 feet and 800 feet chalcopyrite is the chief ore mineral, but below 800 feet bornite is more abundant. The ore is practically free from gold and silver.

Part of the chalcocite found near the surface was undoubtedly of supergene origin, but that occurring at depths is clearly primary. It is generally in intimate intergrowth with bornite, and is still abundant at a depth of 900 feet. Bornite is slightly later than chalcopyrite, and has developed in part by the replacement of that mineral. The sulphides occur in nodular masses rather than in finely disseminated grains.

Above water-level the sulphides were represented by malachite, azurite, cuprite, chrysocolla and native copper. A little covellite was found near water-level.

The chief gangue mineral is quartz. This occurs partly as massive coarsely crystalline white quartz, and partly as well-formed quartz crystals arranged in combs and radial aggregates. Quartz is in places accompanied by sodapotash feldspar, which is later than quartz, but earlier than the sulphides. The quartz is often accompanied by specularite, and the crystals of the mineral are generally dusted with green chlorite. The sulphides are moulded on these chlorite-dusted quartz crystals. Epidote, sericite and talc are also present.

The ore-bodies worked are of the nature of irregular discontinuous quartz bodies and big ellipsoidal quartz bodies following well-defined zones of fracture within the main crush zone. The lodes can be referred to two main systems, namely, those striking between N. by E. and NNE, and those striking approximately NE. They all dip steeply to the ESE, or SE.

Most of them would be described as simple lodes. The "K" lode, however, situated some distance east of the others, is a fine example of a composite lode. It consists of a number of parallel veins of quartz from 4 to 10 feet in thickness, carrying copper sulphides, which are separated by slabs of country rock up to 15 feet in thickness; the main quartz veins being linked up by stringers of that material.

The most persistent of the lodes has been the North lode, which has been opened up over a length of strike of 1,200 feet and carried good copper values to a depth of 600 feet.

The most prolific producer, however, is the much shorter Hanging-Wall lode. This has carried workable ore from the surface to the greatest depth at which the lodes have so far been opened up. It is regarded as the main ore-bearer in the western part of the mine, as it invariably gives rise to rich ore-shoots where it intersects the other lodes. Thus the most valuable ore-body so far found in the mine, namely, the "Gringo Shoot," was struck at a depth of 900 feet at the intersection of the Hanging Wall lode with the normally barren Footwall lode. A feature of the former is the presence of large and small angular inclusions of gneiss. These show the same type of alteration as the wall rock.

The Middle lode terminates north-north-eastward on the 4th level of the mine in a big lenticular ore-body.

The bulk of the ore occurs in shoots which, as already indicated, are often found as lode intersections or at the intersection of the lodes with cross fractures. The shoots are generally of limited extent, but shoots up to 500 feet in length and up to 60 feet in width are encountered. They pitch within the fissure zones at angles generally greater than 60 degrees, and vary much in width going downward. Near the surface the shoots consisted almost exclusively of ore minerals, and averaged over 20 per cent. of copper. At depth even in the richest shoots quartz and other gangue minerals are, without exception, quite as abundant as the sulphides and generally preponderate. There can thus be

no question that the lodes are becoming poorer as they are followed downward.

One of the outstanding features of the lodes is the profound alteration which the rocks enclosing them have undergone. They are all bordered by broad alteration mantles. These consist of an inner zone in which prehnite and dellessite, generally accompanied by laumontite, are the predominant alteration products, and an outer zone in which, according to M. Weber, the place of these minerals is taken, by what has been determined by him as zoisite.

The upper surface of ground water now stands at about 150 feet from the surface of the ground, and the water content falls off greatly in quantity below about 400 feet. Secondary enrichment of the ores due to atmospheric waters has not taken place on any considerable scale, and the chalcocite present is for the most part of deep-seated origin.

MIXING

The Messina Transvaal Copper Company, Ltd., operates the Messina Mine on the farm Berkenrode 1425, and the Harper Mine Vogelenzang 1423. The Northern Transvaal Copper Company is operating on Oostenryk 1421 WSW. of Messina in the same copper belt.

The Messina Copper Company employs 276 whites and 3,000 natives.

The mines hoist 24,000 tons of ore assaying 2.7 per cent. copper monthly, from which 600 tons of ingots assaying 99.8 to 99.9 per cent. copper are produced.

The Messina Mine has been developed to a depth of 2,200 feet, with levels 100 to 150 feet apart vertically. The Harper mine is opened to a depth of 1,000 feet. Because of the irregularities in the shape of the ore-bodies it is not practical to develop by a regular system of drives and raises, and as far as it is possible new ore is opened up by subsidiary winzing and raising in known ore-bodies and by following the ore in stoping.

Development by machine drilling is done exclusively by European labour, and the stoping by native hammer-boys who drill from 24 to 36 inches of hole per day. The ore is broken by underhand stoping when the back and hanging wall conditions will permit of its use. Ordinary shrinkage or a modified form of shrinkage stoping is used where the ground is heavy. In the modified form of shrinkage stoping the back is supported by sprags, posts or cribs resting on

the ore-fill and wedged against the back or hanging. The ore broken in excess of that required to fill the stope is lashed through cribbed boxes carried up through the broken ore.

On the main levels the ore is trammed from stope ore chutes to shaft station pockets by means of 25 cu. ft. cars with 15-inch wheels running on ball bearings. Certain of the shafts through which ore is hoisted have only one combined skip and cage compartment. The shaft is served by a single drum electric hoist with an overbalance counter weight arrangement. Pillars 12 to 20 feet thick are usually left under the drives to support the track in underhand stopes, and over the drives to support the ore-fill of shrinkage stopes. Very little timber is ordinarily required to support the excavations.

The Messina mine is ventilated by three fans located on the surface and drawing air through shallow ventilation shafts which connect with the stopes and development headings below. Ventilation of dead ends is accomplished by 20 h.p., 3,000 r.p.m. portable electric fans blowing air through steel or canvas portable air piping. Dead-end stopes are ventilated by hand forge type blowers connected to sheet canvas air pipes.

The estimation of ore values in the workings is made by measuring the length of ore sulphides along imaginary lines drawn 5 feet apart across the faces and hanging. This is supplemented by sketches of the ore and gangue minerals. From the plotted results of such surveys made once or twice a month the assay value of the ore is calculated for each working section of the stope. The results check with mill results and are found more satisfactory than ordinary mine sampling.

Mining Costs

All development is done by machine drills run by European labour. The total cost per foot advanced in all headings is 60s., of which labour costs 15s. 7d. per foot.

All stope drilling is done by native hammer-boys. They receive 1s. 8d. and up to 2s. 2d. per shift, and drill one 24 to 36-inch hole per day.

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The cost of ore-breaking in stopes is as follows:—

	Shillings.
Hammer-boy labour per ton broken	2·27
Supervision, European miners and boss boys ...	0·70
Explosives and candles	1·18
Steel and steel sharpening	0·32
Supporting ground	0·63
Boulder breaking and lashing	0·37
Miscellaneous	0·70
Total per ton broken (shillings)	6·17
Tons broken per hammer-boy shift	1
Feet drilled per hammer-boy shift	2·62

Experiments have been made in stoping with portable 50 lb. drills operated by Europeans. The tonnage broken per machine shift is 40, and 75 feet of hole is drilled. The cost works out at about 7·03 shillings per ton broken. Because of the many small and lean stopes, the irregularity of the ore-bodies, and other reasons, hammer-boy drilling is preferred in the stopes.

EXTRACTION OF THE COPPER

Concentration of the ore is effected by gravity concentration combined with flotation. The ore is ground in Cole ball-bearing rod-mills and concentrated in Woodbury cast-iron jigs and over Deister tables. A special machine designed at Messina is used for flotation. The reagents are pine oil and creosote. The plant recovers 95 per cent. of the copper in the ore as it comes from the mine and delivers 40 per cent. concentrates to the smelting plant. The smelting plant consists of a smelting furnace which produces a 65 per cent. copper matte, a stationary converting furnace and a refining furnace. Pulverized coal is used for fuel. The furnaces are placed on different levels, so that the matte gravitates into the converter, and the blister copper from the converter flows by gravity into the refining furnace. The refined copper ingots assay 99·88 per cent. copper. They are free from lead, zinc, arsenic and other impurities. The amounts of gold and silver are too small to be of value.

PRODUCTION

The following table gives particulars of the tonnage and value of copper sold in and shipped from the Union from 1857 to the end of 1928:—



Plate XXVI.—Cliff of pure hematite ore Sovereign Hill, Crocodile Ward, Rustenburg district.

[Photo, P. A. Wagner.]



Plate XXVII.—Outcrop of hard manganese ore, western belt, Postmasburg.

[Photo, A. W. Rogers.]

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Year.	Cape.			Transvaal.		
	Tons. \$	Per cent. of Metal.	Value.	Tons. \$	Per cent. of Metal.	Value.
			£			£
1857-1862	22,343	—	605,458	—	—	—
1863-1882	211,500	—	4,308,433	—	—	—
1883-1903	943,658	18.99	8,336,509	—	—	—
1904	—	—	—	14	—	668
1905-09 av.	*	*	484,833	981	*	30,934
1910-14 av	13,858†	47.30†	430,901	5,428	44.95	126,442
1915	13,973	44.48	517,208	14,996	43.38	525,106
1916	10,599	44.52	474,076	12,243	47.40	663,304
1917	10,525	47.66	550,642	9,606	51.44	575,398
1918	1,669	48.51	68,622	5,206	53.28	273,483
1919	276	74.62	17,656	4,610	60.70	216,789
1920	7,892	58.33	255,157	2,988	64.61	163,112
1921†	113	72.60	5,026	45	51.27	1,420
1922	706	93.33	38,622	—	—	—
1923	2,846	97.19	159,713	6,613	61.03	244,798
1924	3,384	97.51	187,745	6,575	85.63	343,079
1925	2,995	98.16	160,074	6,967	86.70	354,145
1926	3,274	98.46	165,017	5,961	99.11	329,835
1927	2,909	98.44	141,779	7,898	99.68	435,340
1928	2,802	98.46	164,315	7,102	99.87	439,237

* No record

† Average of 1911-14.

‡ Mining practically at a standstill.

§ 1 ton equals 2,000 lb.

IRON HISTORICAL

Iron ore is one of the metals that was extensively mined in Africa before the advent of the Europeans. Ancient workings of iron ore and old furnaces are scattered over the Transvaal, Natal, Zululand and Griqualand West. Ochre and specularite were excavated in some places for painting the body and powdering the hair. In other places the ore extracted was smelted and the iron used for the making of weapons and tools. In parts of South Africa this primitive industry is still being practised. The iron ore at Prestwick, Natal, was known to Europeans as early as 1860 or thereabouts. In 1870 President Burgers of the Transvaal Republic obtained specimens of the titaniferous iron ore that outcrops in great quantities to the north of Pretoria from H. W. Struben, who later helped to discover the Witwatersrand. Burgers took these to Europe, but failed to interest anyone in them. In 1901 C. L. Green attempted to smelt iron near Pietermaritzburg, but the venture was not a commercial success. In 1908 Sir Robert Kotze, in a report to the Parliament of the Transvaal, urged the desirability of encouraging the establishment of a steel and iron industry by a bounty system, and pointed out that steel could be manufactured at a profit from scrap iron in small electric furnaces. In 1912 a smelting works was erected at Vereeniging by the Union Steel Corporation for

the smelting of scrap iron, and another was erected by the Dunswart Iron and Steel Works near Benoni. These have been in operation ever since.

In 1917 two small blast furnaces were erected, one in Pretoria and the other at Vereeniging, and these did useful work in testing the suitability of many South African ores for the production of pig iron. In order to encourage the production of pig iron from South African ores, the Government passed the Iron and Steel Bounties Act in 1922, which granted an initial bounty of 15s. per ton to companies capable of producing not less than 50,000 tons a year of iron or steel. In 1924 a commission from Europe investigated the possibilities for making steel in South Africa, and returned a favourable report. A blast furnace was erected at Newcastle and started operations in 1926. This has a capacity of 150 tons of pig iron per day. In 1928 the Government, by Act of Parliament, established the South African Iron and Steel Industries Corporation, Ltd., for the manufacture of pig iron and steel within the Union. The Government is to assist by subscription and the guarantee of debentures in raising a part of the capital required for the venture.

THE ORE-BODIES

The Union of South Africa possesses fairly large reserves of high-grade and vast reserves of medium-grade iron ores, the most important deposits being situated in the Transvaal.

The principal occurrences may be classified as follows:

1. Deposits formed by magmatic segregation;
2. Replacement deposits connected with igneous rocks;
3. Deposits of sedimentary origin;
4. Deposits of the Lake Superior type.

DEPOSITS FORMED BY MAGMATIC SEGREGATION

Here belong the great stratiform segregations of titaniferous magnetite occurring in the upper part of the norite zone of the Bushveld igneous complex of the Transvaal. They occur near the platinum occurrences of the Merensky horizon but higher in the norite body (see Figure 8). They are up to 15 feet in thickness, and can be traced for hundreds of miles. They thus contain vast reserves of ore, but owing to their high titanium content, which ranges from 16 to 19 per cent., there is no prospect of their being utilized in the immediate future. An analysis of a typical specimen of the ore is given in Table 1, page 193.

There is also an important deposit of titaniferous magnetite of magmatic origin in the Tugela Valley below

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Middel Drift, in Natal. Analyses show from 9·2 to 19·7 per cent. of titanium oxide, and from 42 to 54 per cent. of iron.

REPLACEMENT DEPOSITS CONNECTED WITH IGNEOUS ROCKS

The most important deposits under this head are situated on the farm Kromdraai 459, 40 miles north-north-east of Pretoria. (Figure 12.) They are stratiform replacements in a series of conglomerates, grits and tuffs intercalated with the felsites of the Rooiberg series. The dip of the iron deposit conforms to that of these rocks, which is to the south-east at from 10 to 12 degrees. The ore consists mainly of small crystals of specularite. It is very free from phosphorous and sulphur, but on the other hand rather siliceous. Thus a representative sample over a thickness of eleven feet in the main exposure of what is known as the "blue" ore, occurring at the centre of the deposit, contained 60·5 per cent. of iron and 13·7 per cent. of silica. Another partial analysis of this type of ore is given in Table 1. Apart from the "blue" ore, of which only a relatively small tonnage is present, there are moderate reserves of "purple ore" of the same grade and large reserves of more siliceous "red" ore, interspersed with pebbles and fragments of felsite.

Lesser occurrences of specularite ore are widely distributed in the Rooiberg series, the source of the iron being the Red Granite of the Bushveld complex.

To the same category as these deposits may be referred the occurrence on Beechwood 1405, situated west-north-west of Nylstroom. It is of the nature of a replacement deposit following a line of fissure in felsite. The ore is hematite containing up to 4·1 per cent. of manganese.

DEPOSITS OF SEDIMENTARY ORIGIN

There are very important deposits of sedimentary iron ores in the Pretoria series of the Transvaal system and in the Ecca series of the Karroo system.

Iron Ores of the Pretoria Series

These can be referred to three main horizons, namely:—

- (a) The so-called magnetic quartzite. (Figure 15.)
- (b) The clay band.
- (c) The Daspoort horizon.

(a) This is an extraordinarily persistent bed of fine-grained, arenaceous, oolitic ironstone ranging from 7 to 20 feet in thickness, which can be followed for hundreds of miles. It is conformably inter-stratified with the quartzites and shales of the Timeball Hill zone of the Pretoria

series, which, near Pretoria, dip to the north at an average angle of 25 degrees. It consists of small oolites made up of alternating concentric layers of magnetite, hematite and chamosite, detrital grains of quartz and crystals of magnetite. The magnetite crystals replace oolites and quartz grains alike, and are evidently due to the recrystallization of part of the iron oxide present.

The iron content of the rock ranges from 40.5 to 54 per cent., and the average silica content ranges from 18 to 21 per cent. The ore attains its best average grade on the Pretoria townlands. The analysis of a representative sample is given in the Table, page 193.

(b) This is a thin bed of oolitic ironstone ranging from 8 inches to 3 feet in thickness, and lying about 180 feet above the magnetic quartzite. As developed at depth it consists of oolites of chamosite and magnetite lying in a matrix of siderite and chamosite. Above water-level the siderite and chamosite have been oxidized to limonite and clayey matter, and the ore has the character of an argillaceous ironstone, hence its name.

(c) This is made up of one or two beds of oolitic ore, recrystallized oolitic ironstone lying some little distance below the Daspoort quartzite. It attains its greatest development to the north of Potchefstroom, where the main bed, ranging in thickness from 2 to 8 feet, can be traced for miles, and averages between 45 and 50 per cent. of metallic iron.

Iron Ores of the Ecra series of the Karroo system.

Thin seams and attenuated lenses of iron ore are interstratified with the sandstones and shales of the Coal Measure series of the Karroo System at many localities in Natal and the Transvaal. They are up to 6 feet in thickness, but the average thickness is between 18 inches and 2 feet. The ore is variable in character. It may consist of soft, earthy limonite and hematite, or of banded siderite, or, as at Prestwick, near Dundee, Natal, of black carbonaceous siderite ("Black band" ore). In some localities these ores have been converted by the contact action of sills of Karroo dolerite into hard compact magnetite (Roodepoort 67, Ermelo District, Transvaal).

The ores are for the most part of excellent quality. The ore near Prestwick is being exploited for the Newcastle blast furnace of the Union Steel Corporation.

An analysis of an outcrop specimen of the Prestwick ore, above referred to, is given in Table 1.

DEPOSITS OF THE LAKE SUPERIOR TYPE

Important hematite deposits of the Lake Superior type, that is, secondarily enriched sedimentary ores deposited originally as sideritic cherts, occur in the Crocodile Ward of the Rustenburg District of the Transvaal, north-north-west of Pretoria, and near Postmasburg, in Griqualand West. In the first-named area the deposits lie athwart the Crocodile River between latitudes $24^{\circ} 35'$ and $24^{\circ} 40'$ S. They take the form of lenticular or tabular bodies of hematite ore occurring at the base and at the top of a thick zone of banded ironstone. This is referred by some geologists to the base of the Pretoria series, and by others to the top of the dolomite. The latter view has much to support it. The individual deposits are up to 1,000 yards in length and up to 50 feet in thickness. The hematite is of exceptional purity (see Table 1), and these are without doubt the most important occurrences of high-grade iron ore so far discovered in South Africa. (Figure 12 and Plate XXVI.)

The ore clearly owes its origin to a process of secondary concentration whereby the original siliceous layers of certain sections of the zone of rock that is now banded ironstone were replaced by secondary iron oxide, giving rise to bodies of massive ore composed of alternating layers of primary and secondary hematite.

Identical and almost equally important deposits of high-grade hematite ore are developed in Griqualand West in the Klipfontein-Thakweneng range north of Postmasburg. Here again the ore forms lenses in banded ironstone, in part much brecciated. One of the lenses on the farm Klipfontein, situated some 12 miles south by east of Postmasburg, has a maximum thickness of over 120 feet. The ore is almost identical with the Crocodile River ore, but contains slightly more phosphorus and sulphur.

The Blink Klip Breccia of Griqualand West

Forming a special phase of this type of deposit are the very extensive occurrences of iron ore in the uppermost horizon of the dolomite series near Postmasburg in Griqualand West. They represent, according to A. W. Rogers, a concentration of iron from the originally overlying Pretoria beds along fissures and circular or elliptical areas of subsidence in the dolomite. The ore, as typically developed, is a breccia composed of fragments of banded jasper cemented together by hematite, the silica of the jasper fragments being often completely replaced by hematite. There is a considerable development of this type of ore in the Gamagara Ridge west and north-west of Postmasburg. The iron

content ranges from 38.1 to 67.4 per cent., and very large reserves of high- and medium-grade ore are available.

In certain localities the normal fine-grained hematite of the Blink Klip breccia ore is replaced by specularite. This is the case at Blink Klip Kop, three miles north-east of Postmasburg, where there is a fairly big body of pure specular iron ore.

Deposit on Magdala 818, Zoutpansberg District, Transvaal

What are evidently highly metamorphosed deposits of the Lake Superior type were discovered some years ago on Magdala 818, situated fourteen miles south-east of Messina; the surrounding rocks being composite gneiss and amphibolite. The ore, which is of great purity, is a massive, coarsely crystalline aggregate of hematite and magnetite. The available reserve, however, is small and the deposits have no economic significance.

LATERITIC SURFACE IRONSTONE

The lateritic surface ironstones that have such a wide distribution in South Africa are everywhere too rich in silica to be of value as a potential source of either iron or alumina.

BANDED IRONSTONES OF THE SWAZILAND AND WITWATERSRAND SYSTEMS

The banded ironstones of the Swaziland and Witwatersrand Systems have been investigated at several localities, but were found without exception to be too siliceous to be classed as iron ore.

TABLE 1.—ANALYSES OF IRON ORES.

	I	II	III	IV	V	VI
SiO ₂ ...	0.70	12.10	17.44	5.60	9.15	3.35
TiO ₂ ...	19.20	—	Trace	0.20	—	—
Al ₂ O ₃ ...	Trace	—	7.38	5.90	3.77	0.50
Cr ₂ O ₃ ...	0.65	—	—	—	—	—
Fe ₂ O ₃ ...	49.40	83.65	68.11	36.30	72.41	93.50
FeO ...	28.50	1.90	1.32	34.20	n.d.	2.30
MnO ...	0.35	—	n.d.	—	—	—
MgO ...	1.05	—	0.47	0.60	0.76	—
CaO ...	0.05	—	0.75	0.70	1.70	—
P ₂ O ₅ ...	Trace	Trace	0.39	0.90	0.462	0.05
S ...	0.10	0.02	0.14	0.04	0.068	nil
Co ₂ ...	—	—	—	14.50	—	—
Carbonaceous Matter	—	—	—	—	4.10	—
Moisture ...	0.70	—	4.20	0.15	6.45	0.27
Loss on Ignition				5.10		
Total ...	100.70	97.67	100.30	104.29	98.87	99.97
Fe ...	56.74	60.07	48.60	52.09	52.69	66.23
P ...	Trace	Trace	0.17	0.02	0.202	0.004
S ...	0.10	0.02	0.014	0.39	0.068	nil

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

- (i) Titaniferous Magnetite, Rhenosterfontein 887, Rustenburg district, Transvaal.
- (ii) Iron Ore, Kroondraai 459, Pretoria district.
- (iii) "Magnetic Quartzite" (outcrop specimen) Pretoria townlands.
- (iv) Clay-band Ore (at depth of 148 feet), Pretoria townlands.
- (v) "Black Band Iron Ore (outcrop specimen), Prestwick, 16 miles north-east of Dundee, Natal.
- (vi) Hematite Ore, Buffelshoek 151, Crocodile River Iron Fields, Transvaal.

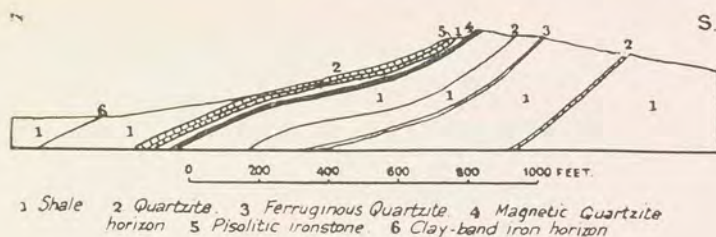
PRESENT STATUS OF THE IRON AND STEEL INDUSTRY

The only blast furnace at present in operation in the Union is that of the Union Steel Corporation at Newcastle, Natal. This was blown in in 1926, and was in intermittent operation for 22 months from that date to the end of April, 1929. During this time it produced 84,392 $\frac{3}{4}$ tons of foundry and basic pig iron. The costs of production ranged from £3 19s. 8d. to £4 8s. 6d. per ton of pig iron. The total quantity of ore that has been mined for use in this furnace is 155,968 tons at a working cost of 5s. per ton, including 6 miles of rail transport. The ore is obtained from beds in the Ecca series at Prestwick. The ore reserves "ore in sight" available for use in this furnace are calculated at 4 million tons of over 45 per cent. metallic iron, which is sufficient to keep the blast in operation for more than 30 years. There is also an adequate supply of coking-coal close at hand.

The South African Iron and Steel Industries Corporation, Ltd., established by Parliament in 1928 are to build their works at Pretoria. They have taken over deposits estimated to contain 155 million tons of iron ore lying in the Pretoria series of the Transvaal system and in the high-grade deposits on the Crocodile River, Rustenburg district. They hold the mining rights over deposits estimated to contain 250 million tons of coal. Just what amount of coking-coal is to be had from these deposits has not been determined. They also hold rights on deposits of manganiferous ore and magnesite. The proposed producing capacity of their plant is to be of the order of 150,000 tons of iron and steel per annum.

At present there are four concerns engaged in the production of iron and steel goods in the Union:—

(1) The Union Steel Corporation of S.A., Ltd., with works at Vereeniging, in the Transvaal, and a total capacity of 60,000 tons of steel ingots per annum. They use both scrap and pig iron.



Section of Iron ore deposits south-east of Pretoria
After P.A. Wagner

FIGURE 15

(2) The Dunswart Iron and Steel Works, Ltd., with works at Dunswart, near Benoni, Transvaal. They use scrap iron only and produce almost 800 tons per month, although their capacity is larger.

(3) Geo. Stott & Co., Johannesburg, with a total capacity of 500 tons and an output of 400 tons per month.

(4) Witwatersrand Co-operative Works, Ltd., with works at Driehoek, in Johannesburg. Their output and capacity is about 400 tons per month. The total capacity of these four concerns is about 80,000 tons per year, and the actual production, exclusive of pig iron, was 45,000 tons of rolling-mill products and castings in 1928.

The value as ore of the total production of iron ore in the Union of South Africa up to the end of 1928 is given at £60,563. In addition, iron pyrites, which is used for the manufacture of sulphuric acid, was produced to the value of £69,646.

ORE RESERVES

Wagner states that rock that contains less than 40 per cent of metallic iron, and at the same time over 25 per cent. of silica, cannot be economically smelted. This he adopts as a standard for classifying ore in calculating the iron ore reserves in the various deposits listed below. Spathic iron ores such as those that occur in Natal are, however, calculated on a lower iron content. He estimates that ore of an average thickness of not more than 2 feet cannot be worked to a greater depth than 1,000 feet vertically from the surface, and that for deposits of a thickness of 5 feet or more, the economic limit of mining is a depth of 4,500 feet. The probable reserves are divided as follows:

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

PROBABLE ORES

1. High-grade ore carrying approximately 60 per cent. of metallic iron and from 1 to 5 per cent. of silica:—

	Tons of ore.
Lake Superior Type: Buffelshoek - Gatkop, west of Warmbaths, Transvaal	92,000,000
Lake Superior Type: Leeuwbosch, west of Warmbaths, Transvaal	1,000,000
Lake Superior Type: Gamagara Ridge and vicinity, Griqualand West	28,280,000
Karoo Deposits: Ermelo and Middelburg Districts, Transvaal	200,000
Total	121,480,000

2. Medium-grade ore approximately 40 to 60 per cent. of iron and 5 to 25 per cent. of silica:—

	Tons of ore.
Sedimentary deposits magnetic quartzite horizon, Pretoria series, Transvaal	4,840,000,000
Pisolithic ironstone immediately over magnetic quartzite, Pretoria series, Transvaal	6,200,000
Clay band horizon, Pretoria series, Transvaal	19,800,000
Daspoort horizon, Pretoria series, Transvaal	1,034,130,000
Replacement deposits, Kromdraai, Transvaal	4,400,000
Karoo sediments, Prestwick, Natal	2,400,410
Other Karoo deposits, Natal	3,000,000
Total medium-grade ore	5,909,930,410

Mr. T. Nimmo Dewar gives the actual ore developed and in sight at Prestwick at 3,000,000 tons, potential ore at 20 million tons, and states that deposits at this horizon probably underlie 600 square miles up the Klip River country of Northern Natal, which increases the potential ore on this horizon to a colossal figure.

POTENTIAL ORES

In addition, Wagner estimated the probable titaniferous iron ores of the Transvaal Bushveld, together with the same type occurring in ancient gabbros in Piet Retief, Transvaal, and in Zululand at 2,142,000,000 tons. These carry from

12 to 20 per cent. TiO_2 and cannot be smelted under present conditions. In addition, potential ores of iron content less than 40 per cent. and carrying high percentages of silica are estimated at 2,286,020,000,000 tons. These are also of no economic importance under present conditions.

The total probable reserve of usable iron ore is therefore, according to Wagner, in the neighbourhood of 6,000,000,000 tons. This is, according to the same author, exceeded only by the reserves of iron ore in India, the United States, Brazil and France. South Africa possesses also large resources of the other materials that are necessary for the manufacture of pig iron and steel, such as coking-coal, manganese and other ferro-alloy ores, fluxing materials and refractories.

TiN

Tin is one of the metals that was mined extensively in Southern Africa at times and periods before the European set foot in the country. There are no historic records to show who the miners were and when mining took place. There is evidence to show that the people who mined tin were also interested in copper, and were makers of bronze utensils. Within the area of the present Rooiberg Tin Mine and covering an area of approximately 75 acres, there are extensive old workings consisting of open-casts, small circular shafts and tunnels. None of these appears to have gone deeper than 50 feet from the surface. A smelting site existed in a low knoll near-by, and there probably all of the 18,000 tons of ore that is estimated to have been mined from these excavations was smelted to tin. From the smelting site a graded road, about six feet wide, goes up the steep face of a ridge to the north of it, and from there it takes a remarkably straight course over hill and dale to old smelter sites 10 or 12 miles to the north. Beyond these it again climbs up a steep ridge, maintaining a good grade all the way. The road is evidently pre-European; it appears to have been made for vehicular traffic, and it trends in as straight a line as possible toward the ancient copper mines far north at Messina. This suggests that the tin was used in conjunction with copper for the manufacture of bronze utensils. Bronze fragments as well as tin ingots of ancient origin have actually been discovered

near Rooiberg. Though iron gads and other evidences indicate that work may have been in progress there a few centuries ago, there are archaeologists who state that it was worked some thousands of years before our day. After lying fallow for hundreds or thousands of years, as the case may be, the Rooiberg mines, with other Transvaal occurrences, were re-discovered in 1905. Ten or fifteen years before then deposits of tin had been found in the Cape Province and Swaziland.

The total value of tin produced in the Union up to the end of 1928 was £6,324,262; of this the Cape Province produced £62,482 and the Transvaal the remainder.

For the last five years the Transvaal has produced tin concentrates of an average value of over £300,000 per annum. Apart from a small recovery of alluvial concentrates at Kuils River, in the Stellenbosch district, there is no output from the Cape at the present time.

ORE-BODIES

The principal deposits are situated in the Transvaal, and occur in or in association with the Red Granite of the Bushveld complex and in the felsites and sedimentary rocks of the Rooiberg series forming the roof of the complex.

The known occurrences are confined to an area of about 100 by 70 miles in the central part of the Bushveld complex, lying between latitude 24° and $25^{\circ} 30'$ S. and longitudes $27^{\circ} 40'$ and $29^{\circ} 20'$ E. Within these limits the red granite and the granophyric rocks associated with it form a great composite sheet or lopolith. Wherever the upper portion of this sheet is exposed, or its original roof of felsite, felspathic quartzite or shale is preserved, cassiterite has been found. The richest deposits appear to be connected with anticlinal or domal structures in the original roof. In the eastern part of the Bushveld complex, on the other hand, east and north-east of Middelburg, where identical geological conditions prevail, no cassiterite deposits have as yet been discovered.

The tin deposits of the Bushveld complex are as varied as they are numerous. They bear, however, a common stamp which points to their having been formed during the same period of metallization and under much the same conditions. Thus all the deposits that have been carefully studied have the same history, and their formation has taken place in a number of distinct stages; an early pegmatitic or magmatic stage having been succeeded by a

pneumatolytic stage when cassiterite was deposited, and this in turn by one or more strictly hydrothermal stages.

The deposits are most conveniently classified as follows, according to the nature of the rock in which they occur:—

1. Deposits in red granite.
2. Deposits in granophyre.
3. Deposits in felsite.
4. Deposits in sedimentary rocks of the Rooiberg series.

In certain areas, e.g., the Mutue Fides- Stavoren fields, where there is exposed a continuous section from the granite to the Rooiberg series, it is evident that the kind of country rock is correlated with the conditions of temperature and pressure under which the mineralization took place. Thus the deposits in granite, which are the lowest topographically and were evidently formed at the highest temperature and pressure, are essentially tin deposits. The deposits in the overlying granophyre, formed at a somewhat lower temperature and pressure, are cassiterite-scheelite-chalcopyrite deposits, and the deposits in the quartzites of the Rooiberg beds are cassiterite-chalcopyrite-wolframite deposits, which, moreover, contain considerable quantities of specularite. In other areas, however, there is no relation between the nature of the mineralization and that of the country rock. Thus the lode deposits of the Rooiberg and Leeuwpoot fields, though they are in Rooiberg beds, are essentially tin deposits, tungsten and copper minerals being quite subordinate to cassiterite.

DEPOSITS IN GRANITE

The most important deposits in granite are those of the Potgietersrust fields, situated fifteen miles north-west of Potgietersrust. They embrace a narrow strip of rugged country some fourteen miles in length paralleling the Potgietersrust platinum belt, previously referred to, which is situated some ten miles to the east.

Tin deposits occur in a great composite sheet of red granite, dipping at an angle of about 15 degrees to the west, which was apparently slightly later than a thick overlying sheet of granophyric rocks which, in turn, was intruded in a succession of felsites and shales that here formed the roof of the Bushveld complex. The upper limit of the tin-bearing granite is defined by a persistent pegmatite zone containing a number of distinct sheets of coarse pegmatite which clearly crystallized in place from above downwards.

The main granite sheet is, as already indicated, composite in character. It consists in its basal portion of porphyritic granite. This is succeeded by alternations of coarse-grained pink and red granite and aplitic granite. Above this there follows a thick zone of miarolitic granite, which in turn merges into fine-grained aplitic granite showing pronounced pseudo-stratification. The aplitic granite is limited above by the pegmatite zone already referred to, and if this interpretation be correct, probably represents a chilled marginal phase of the coarse red granite.

The most important deposits occur immediately or at a short distance below the pegmatite zone on the farms Groenfontein 871, Roodepoort 813 and Zaaipplaats 236. They occur in the coarse miarolitic granite and in the fine-grained granite overlying it. There are also important deposits following the lower contact of the pegmatite and in the pegmatite itself (Figure 12).

The deposits are of four main types, namely:—

- (a) Pipes ;
- (b) Irregular impregnations in miarolitic granite ;
- (c) Replacements along fissures in the fine grain aplitic granite, or along the pseudo-bedding planes of that rock ;
- (d) Tabular replacements following the lower contact of the pegmatite or in the pegmatite.

(a) Of these the pipes are by far the most interesting and important. They are of the nature of irregular tubular bodies of mineralized altered granite of circular or oval cross section. They range in greatest diameter from a foot to 40 feet, and descend at varying angles into the granite in a general west-north-west east-south-east direction. The pipes occur in groups, and it has been the general experience that those outcropping in close proximity to one another unite in depth, forming complex branching ore-bodies (see Figures 16 and 17).

On Zaaipplaats, for example, what were originally taken to be about 25 separate pipes have resolved themselves into two main pipe systems known respectively as the "No. V.-VI." and the "No. XIII." pipes. Of these the former has been followed for a distance of over 2,000 feet measured along the incline, and the "No. XIII." pipe for over 2,500 feet, equivalent to a vertical depth of 688 feet.

The pipe matter is of two main types. Commonly it consists of a soft yellowish-grey brown-spotted aggregate composed of crystals of cassiterite averaging about 1.5 mm.

across, scattered through a matrix made up mainly of small flakes of sericite, in which the outlines of much altered grains of feldspar can usually be made out. A good deal of calcite is generally present, and isolated relics of the original quartz of the granite are sometimes to be seen. In addition, chlorite and fluor spar and one or more of the ore minerals, to be subsequently enumerated, may be present.

The other type of ore is essentially feldspar-cassiterite rock, being composed largely of red or pink microperthite indistinguishable from that of the surrounding granite except in that it often exhibits idiomorphic outlines. Subordinate amounts of gilbertite, chlorite, and purple fluor spar are generally present, and the cassiterite may be accompanied by arsenopyrite, pyrite and chalcopyrite. This type of ore has clearly developed as a result of the replacement by cassiterite of the quartz of the normal granite, while the feldspar remained unattacked.

In the type first dealt with the replacements of quartz by cassiterite was succeeded by the replacement of feldspar by sericite, calcite and other minerals. In some pipes this soft sericite ore has suffered secondary impregnation by quartz. In others the pipe matter has been largely replaced by grey or brown chalcedonic silica evidently deposited as silica gel.

The ore is sometimes zonally banded parallel to the outer periphery of the pipes.

In the upper parts of the "No. V.-VI." pipes on Zaai-plaats there were found big elongated vugs lined with crystals of fluor spar, quartz, calcite, chalcopyrite, galena, and zinblende; the three last named minerals sometimes forming concentric crusts.

Sometimes there is a direct transition from ore through sericitised granite to unaltered granite. Frequently, however, the pipe-matter proper is encased in remarkable "tourmaline-rings," from $\frac{1}{2}$ inch to 4 feet in thickness, composed of radial and fan-shaped aggregates of black tourmaline needles in a matrix of white quartz. These rings are, as a rule, in turn surrounded by a narrow zone of white quartz, and this by a zone of fresh-looking granite which, under the microscope, is found, however, to owe its fresh appearance to secondary impregnation by quartz, generally accompanied by calcite. Outside this follows a zone of granite in which the biotite of that rock, and sometimes the feldspar, are replaced by sericite, and then the normal granite.

0 500 1000 Feet

RED GRANITE

RED GRANITE

N V
N IV
N III

LONGITUDINAL SECTION

FIGURE 1

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Some of the pipes have proved remarkably rich, but in all of them rich sectors have alternated with poor and barren sectors occupied by more or less altered granite free from cassiterite. The latter generally coincide with the sectors of the pipes showing flat dips.

As to the origin of these remarkable pipes, it is quite certain that they are independent of fissures in the granite. They evidently date from a period when the state of consolidation of that rock did not permit the formation of fissures. These, however, may have been represented by potential planes of weakness.

Of the other occurrences the most interesting are the replacements below the pegmatite. These as a rule follow well-defined lines of fissure in that rock and in the fine-grained aplitic granite below it. Here also cassiterite has replaced quartz in preference to feldspar, and one finds perfect pseudomorphs of cassiterite after crystals of quartz. The feldspar is usually sericitized, and the granite surrounding these deposits has been converted into a typical greisen. On Groenfontein 871, where these deposits attain their greatest importance, the strike of the productive fissures ranges from E. and W. to W. by N.

Considerable amounts of cassiterite have been obtained from the same type of replacement deposits in coarse red granite, also in some instances below big bodies of pegmatite, on the Mutue Fides tin fields, situated some 70 miles to the south-south-east. Widespread greisenization of the surrounding granite is a feature of the deposits.

On the farm Vlaklaagte 39, situated 54 miles NE. of Pretoria, there were discovered in 1905 small bodies of stanniferous greisen in coarse red granite. Some of this greisen was very rich, carrying up to 40 per cent. of tin. The greisen consists of crystals of cassiterite imbedded in a greyish ground-mass of quartz, sericite and topaz; this being the only authenticated occurrence of topaz in the Bushveld tin deposits.

The ore-bodies, on being opened up, proved to be of such limited extent as to have no economic significance.

DEPOSITS IN GRANOPHYRE

In these deposits typically developed on the farm Stavoren 1872, in the south-eastern part of the Waterberg district, the ore minerals occur as replacements and vug fillings in pipes, veins and sheet-like bodies of feldspar-rich pegmatite, the pipe-form predominating. The deposits are remarkable for the rich and varied assortment of minerals which they contain, and for the strikingly handsome

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

appearance of much of the ore. The chief ore minerals are cassiterite, scheelite, chalcopyrite, arsenopyrite, molybdenite, bismuthinite, galenobismutite, galena and zincblende. The gangue minerals include feldspar, quartz (in four generations), calcite, fluorspar, raven-mica, specularite, sericite and chlorite. The deposits are extremely erratic as to ore content.

It has been suggested that the pegmatite pipes were themselves formed by the replacement of the granophyre, and this is not improbable.

DEPOSITS IN FELSITE

These have so far proved very disappointing. They are, as a rule, rather ill defined and patchy, consisting of small irregular veins and pockets carrying fairly coarse cassiterite, sometimes distributed over a fairly considerable width of country rock. On the farms Rhenosterhoek Spruit 1608 and Uitkyk 2241, situated 30 miles west of Nylstroom, there is being opened up a series of parallel vertical tin-bearing crush zones in felsite.

DEPOSITS IN THE SEDIMENTARY ROCKS OF THE ROOIBERG SERIES

These include the interesting lode deposits of the Rooiberg and Leeuwpoot tin fields, and a lode on Doornhoek 896 in the Waterberg district.

The Rooiberg Tin Fields

These lie some 40 miles west of Warmbaths, the most important deposits being situated on the farms Leeuwpoot 938, Weynek 763, Olivienbosch 939, where there are extensive ancient mine workings, Blauwbank 433, and Nieuwpoot 11. The deposits take the form of well-defined lodes with which are connected large irregular replacements generally following the bedding planes of the enclosing, low-dipping, felspathic quartzites.

Tin ore is produced at Leeuwpoot, Rooiberg and Nieuwpoot mines in this area. The ore-bodies occur in quartzites of the Rooiberg series below a zone of shale-bearing quartzite, and range from the shale zone to about 800 feet in section below it. Leeuwpoot and Rooiberg, which are ten miles apart, lie on opposite flanks of a broad major anticline trending north of east, while Nieuwpoot, six miles east of Rooiberg, is on the south side of what is probably an extension of the same major structure, complicated at this locality by a sharp synclinal cross fold trending north-west.

The minerals occurring in the ore-bodies at Leeuwpoot are cassiterite, pyrite, chalcopyrite, martite, specularite, orthoclase, plagioclase, sericite, green mica, kaolin, chlorite, ankerite, quartz, tourmaline, apatite and fluorspar. The abundant minerals at Rooiberg are cassiterite, pyrite, some chalcopyrite and hematite in a gangue of tourmaline, sericite, quartz and ferruginous calcite. Chlorite and orthoclase occur in places, and more rarely scheelite, galena, zincblende and gold. The more abundant minerals present in the Rooiberg have all been recognized at Nieuwpoot. Of the ore that goes through the mill at Leeuwpoot, about 10 per cent. consists of iron compounds, 80 per cent. of which is pyrite; at Rooiberg the proportion is only 2 per cent., most of which is pyrite, and at Nieuwpoot it is still less. Nieuwpoot ore is of finer grain than either of the other two. Tourmaline, which is abundant at Nieuwpoot and Rooiberg, occurs in comparatively small amounts at Leeuwpoot.

The principal ore-bodies in this field occur as lodes in fissures. They are from a few inches to a few feet, rarely over 10 feet in width and in many cases hundreds of feet in length. Tin occurs also in irregular and chimney-like deposits that lie in most places near a major fissure and in many cases between intersecting fissures. There is a tendency also for the ore to form sheet-like deposits along the bedding planes of the sediments.

The Spruit Lode, which is the principal ore-body at Leeuwpoot, is a tabular one which lies parallel to the bedding planes of the quartzites; other such lodes cut across the bedding. They vary in width from 1 to about 4 feet. A series of lodes have been opened along the sides of a ridge called the "Kopie" in the camp. The strike of these ore-bodies is parallel to the adjacent contours of the kopie, and the impression gained is that the fractures carrying ore, and the ridge itself, are due to the same structural cause, that is a protrusion from the roof of the red granite below.

At Rooiberg the ore occurs in lodes within well-developed sets of parallel fractures. There are four principal sets of such ore-bearing fractures:—

- (a) The Union series, with an average trend of N. 8° W.
- (b) The Empire series, with an average trend of N. 22° E.
- (c) The Bond Alpha series, with an average trend of N. 64° E.
- (d) The Progress pyritic series, with an average trend of S. 70° E.

Most of these cut across the gently dipping quartzites at angles of from 50 to 90 degrees. The largest production comes from areas in which two or three of these fissure systems intersect. The ore lies for the greater part in fissures, in irregular chimney-like bodies near them, or in wedge-shaped bodies of rock that occur between intersecting fissures.

At Nieuwpoort the two principal lodes converge in depth, enclosing a wedge of country rock in the keel of which is a low grade stockwork. Here again one of the ore-bodies lies roughly parallel to the bedding of the quartzites.

There is evidence to show that the fractures carrying the lodes were formed during the intrusion of the granite. The difference in the mineral content and fineness of ores at Leeuwpoot, Rooiberg and Nieuwpoort is probably due to the varying distances of these ore-bodies from the intrusive batholith of granite below them.

Doornhoek 896

On this farm a good deal of tin was obtained between 1906 and 1909 from a well-defined lode cutting obliquely across the Sterk River shales of the Rooiberg series. The lode strikes east and west and dips to the north at 60°. It averages 18 inches in thickness, and consists of brecciated and highly altered fragments of the country rock cemented by quartz, with which in places cassiterite, sericite, fluorspar, tourmaline, specularite, magnetite and hematite are associated. The cassiterite is exceedingly fine-grained, and cannot as a rule be identified with the unaided eye. The shales on either side of the lode have suffered tourmalinization.

TIN OCCURRENCES OF THE CAPE PROVINCE

The only tin occurrences so far discovered in the Cape Province are situated near Capetown, on the slopes of Table Mountain, in the granite of the Bottelary-Stellenbosch mass, and the rocks of the Malmesbury series near the intrusive contact of this granite.

Four main types of deposit may be distinguished:—

- (1) Veins and associated impregnations in granite;
- (2) Stringer lodes in the rocks of the Malmesbury series;
- (3) Saddle veins in the rocks of the Malmesbury series;

- (4) Alluvial deposits derived from the disintegration of the primary occurrences.

Of the primary occurrences only those belonging to types (1) and (2) have so far been found worth working, but operations were in each case soon suspended. The most important deposits are on the farms Langverwacht and Hazendal, situated 18 miles east of Capetown. They take the form of quartz veins in fine-grained aplitic granite traversing coarse porphyritic granite. These veins carry coarse cassiterite in association with wolframite, molybdenite, arsenopyrite, chalcopyrite, muscovite and tourmaline. Wolframite disappears below a depth of 150 feet.

The disintegration of these deposits has given rise to the formation, in a broad valley and some of the creeks traversing the farm Langverwacht, of fairly considerable alluvial cassiterite deposits which were at one time worked on a big scale. It is from these deposits that the greater part of the output of tin ore of the Cape Province has been derived.

EASTERN TRANSVAAL AND SWAZILAND

The cassiterite in this area is only worked as alluvial, but it is undoubtedly derived from the many large pegmatite veins that traverse the older, or grey granite, which here makes the escarpment of the South African plateau. These pegmatites have not yet been found workable, though cassiterite crystals are not uncommon in them. This area is subject to a very heavy rainfall and strong denudation, and in the valleys running down into Swaziland ideal conditions exist for natural concentration. The tin fields extend on both sides of the border, but at present the production of tin is entirely confined to Swaziland.

The ground is worked by hydraulicking and sluicing. The cassiterite is very coarse; apart from the magnetic separation of the iron in the final cassiterite concentrates, no mechanical dressing is required. About half a million cubic yards of ground is annually treated, giving about 1·8 lb. black tin per yard. The total working cost is about 11·6d. per cubic yard. The concentrates shipped carry 71 per cent. metallic tin, and are remarkably free from any deleterious impurity. Many of the rarer minerals of thorium and tungsten are found in the concentrates, but not in commercial quantities. The export from these fields is about 300 tons cassiterite per year; but this is not included in the returns for the Union.

MINING METHODS¹

The pipes of Zaaiplaats are tubular bodies that change their direction both in dip and strike. In such bodies advance development becomes impracticable and the ore-body is followed and mined out foot by foot. The ore is softer than the surrounding rock and the pipes excavated only 8 or 10 feet and in exceptional cases 40 feet across. The country rock around the pipes is of solid granite and needs practically no extra support. Jackhammers and hammer-boys are used for drilling. Because of the many twists and turns in the pipes, haulage, which is done by electric and steam winches, is difficult and after the pipe has been followed for a certain distance the haulages have to be straightened or stage hauling resorted to. The pipes at Zaaiplaats have been followed to depths on the incline of 2,000 and 2,500 feet, the latter equivalent to a vertical depth of 688 feet. On Rooiberg and Leeuwpoot the lodes which are comparatively straight and consistent in strike and dip were developed and blocked out by a system of shafts, drives, winzes and raises. The ore was first mined by back and later on by underhand stoping. There are numerous irregular ore-bodies branching from the main lodes in flat or chimney-like fashion and in these the ore is simply followed until it is exhausted, leaving a cavity varying in shape for every separate body worked. Some open-casting has been done both at Rooiberg and Nieuwpoort. Where, as at Nieuwpoort, steeply dipping lodes intersect in a nearly horizontal line, and a stockwork ore-body lies in the keel of the wedge, between the lodes and above their intersections, the extraction of the ore and the support of the walls present an exceedingly difficult problem.

Large surface excavations have been made at Leeuwpoot on irregular deposits such as H.G. working. In the Spruit and most of the other workings the ore lies in regular tabular bodies and is mined according to Rand practice.

RECOVERY OF TIN

The metallurgical problems vary considerably. The tin occurrences in the Red Granite lend themselves to a better and easier extraction than those associated with the felsites and Rooiberg quartzites.

¹ Contributed by W. J. Gau, Consulting Engineer, South African Townships Mining and Finance Corporation, Ltd., Johannesburg.

At Zaaipplaats, the ore which is derived from the "pipe-like" and impregnated bodies in the granite is comparatively free from impurities. The cassiterite occurs as coarse and detached crystals and is recovered, after coarse crushing, on jigs and Wilfley tables, the slimes being treated on Frue Vanners and Senn tables. All the concentrates after calcination are finally dressed up for shipment (74% to 75% M.T.) on Wilfley tables and buddles. At the Mutue Fides mine the concentrating process is somewhat similar, the initial crushing of the ore, however, being undertaken in a Huntington mill. The final concentrate grade is about the same as at Zaaipplaats. At both mines the recovery is probably in the neighbourhood of 90%.

The ore at the Rooiberg tin mine is derived from lodes and irregular occurrences in the quartzites and is somewhat pyritic, containing both fine as well as coarse crystals of cassiterite in a fairly "free" state. The treatment consists of crushing by stamps. The primary concentration is over Wilfley and James tables and the slimes are treated by means of round frames, Acme tables and buddles. The calcining of the concentrates takes place in a Brunton furnace, and final dressing on buddles and Wilfley tables. The concentrate for shipment contains about 68% M.T. with a recovery of about 77% to 78% M.T.

The lodes at Leeuwpoort are similar to those at Rooiberg, but the cassiterite is more finely disseminated, and its economic recovery is extremely difficult, mainly on account of its very close association with large quantities of iron in the form of oxides and pyrites, and the very small amount of "free" tin. The method of treatment is elaborate and consists in crushing the ore in a battery of Californian and Nissen stamps. After intensive sorting, grading of the battery pulp is mainly undertaken by Hammer screens and the secondary crushing is done in tube mills. Concentration is carried out on Wilfley tables, the finer products being dealt with on Isbell vanners and Senn concentrators, careful classification being essential to obtain satisfactory concentration results. The calcining of the concentrates was, until recently, carried out in Merton furnaces, which, however, have now been closed down, as it has been found that the iron is eliminated more economically and successfully by the flotation process which floats off the iron-pyrites and not the cassiterite. The final treatment of the concentrates is carried out by

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means of special rotary roasters and the magnetic separation of a large percentage of the iron in specially designed D.C. and A.C. magnetic separators. Despite the elaborate treatment the extraction does not exceed 62% to 63%. The grade of ore is about 1% M.T., after sorting, and the final concentrates about 64% M.T.

PRODUCTION

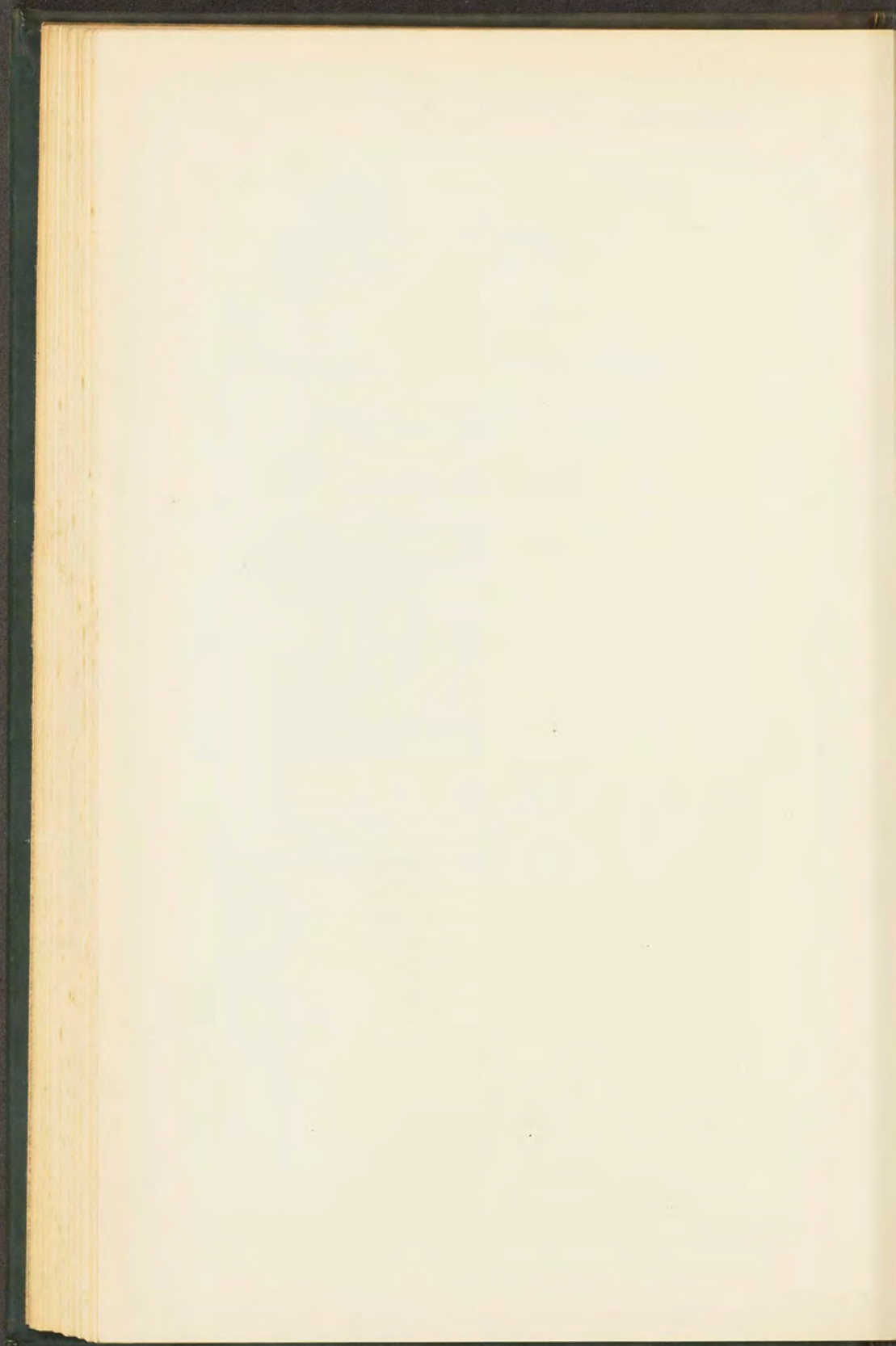
The production of tin concentrates in each of the provinces of the Union of South Africa is given in detail in the following table:—

Year.	Cape.			Transvaal.			Totals for Union.		
	Tons.	Per cent. of Metal.	Value.	Tons.	Per cent. of Metal.	Value.	Tons.	Per cent. of Metal.	Value.
			£			£			£
1911 ...	8	75.13	1,023	3,526	67.24	410,848	3,534	67.26	411,871
1912 ...	—	—	—	2,932	66.64	367,699	2,932	66.64	367,699
1913 ...	71	74.14	8,687	3,601	68.57	427,863	3,672	68.68	436,550
1914 ...	43	71.36	4,109	3,386	66.04	307,282	3,429	66.10	311,391
1915 ...	39	74.60	4,232	3,402	66.85	327,188	3,441	66.94	331,420
1916 ...	29	74.51	3,436	3,235	66.08	336,135	3,264	66.16	339,571
1917 ...	38	71.60	5,692	2,641	66.73	340,324	2,679	66.80	346,016
1918 ...	16	69.01	2,863	2,190	72.18	438,132	2,206	72.16	440,995
1919 ...	32	70.92	5,007	1,598	76.35	272,918	1,630	76.24	277,925
1920 ...	11	74.15	2,314	2,452	69.52	433,366	2,463	69.54	435,680
1921 ...	9	74.59	1,018	1,416	64.53	138,670	1,425	64.59	139,688
1922 ...	—	—	—	612	68.16	59,986	612	68.16	59,986
1923 ...	3	75.50	408	1,421	66.71	169,929	1,424	66.73	170,337
1924 ...	—	—	—	2,051	65.91	305,398	2,051	65.91	305,398
1925 ...	—	—	—	1,939	65.92	304,552	1,939	65.92	304,552
1926 ...	6	76.00	1,055	1,785	67.62	309,844	1,791	67.65	310,899
1927 ...	—	—	—	1,928	67.06	329,947	1,928	67.06	329,947
1928 ...	—	—	—	1,989	67.24	269,285	1,989	67.24	269,285

There are no large bodies of ore in reserve and no data on which to base an estimate of the probable future output. Tin in small quantities will probably be produced in the Union for many years to come.

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CHAPTER VII

OTHER BASE METALS

ANTIMONY

Antimony in the form of stibnite and its oxidation products stibiconite, and senarmonite, is associated with gold in the northern line of reefs of the Murchison range in the Leydsdorp district of the Transvaal. The reefs occur in lenticular masses up to 20 feet wide and 200 feet in length down the dip. The ores contain from 4 to 60 per cent. of stibnite or antimony oxide and in places from 3 to 20 dwt. of gold to the ton. During the Great War one of the mines produced "white metal" for local use. The deposits are connected by rail with the Port of Lourenço Marques at Delagoa Bay which is some 200 miles away. No mines are in operation at the present time. The total value of the antimony produced in the Union up to the end of 1928 is given at £33,279, all of which came from the Transvaal.

ARSENIC

Small amounts of white arsenic (arsenious oxide) are recovered from the roasting of pyritic gold ores at the Maid of De Kaap and Consort mines in the Barberton district. White arsenic was also at one time recovered as a by-product of tin mining at Mutue Fides-Stavoren mine in the central Transvaal. On the farm Houtenbek 392, situated 65 miles north-east of Pretoria and farms south-west of it, there are exposed a number of pegmatite veins carrying the rare arsenic mineral leucopyrite Fe_3As_4 in association with molybdenite.

The total value of the arsenic produced in the Union up to the end of 1928 is given as £10,648, all of which came from the Transvaal. The production has ranged from 21 to 88 tons in the last few years. The Union consumes close on £100,000 worth of arsenic per annum in the form of cattle dips and sprays for trees. It is therefore highly desirable that other deposits of arsenic be discovered and exploited.

BISMUTH

Small amounts of very rich bismuth ore, composed mainly of bismutite ochre, were obtained in the nineties of last century from a deposit on the farm Geweerfontein, situated north of the Elands River, in the northern part of the Pretoria district. The primary ore consists of

arsenopyrite accompanied by subordinate amounts of bismuth glance. It forms isolated replacements in pink felsites. The rich ore was quickly worked out. Attempts made in 1925 to find other ore-bodies by electrical prospecting failed.

At the Dientje mine, situated on the farm Dientje 552, 19 miles north of Pilgrims Rest in the Transvaal, bismuth is associated with gold and copper in vertical lodes in a big dyke of gabbro, and along the contact of the dyke and the Black Reef sandstone in which it is intrusive. The ore minerals are bismuthinite, chalcopyrite, gold and pyrite. The gangue consists of lustrous white quartz accompanied by chlorite along the selvages of the veins.

Recently a promising bismuth lode has been opened up on the farm Rhenosterhoek Spruit 662, situated 14 miles north-east of the Rooiberg tin mine. The ore contains notable amounts of gold and silver.

The bismuth production up to the end of 1928 is given as of the value of £300, all of which came from the Transvaal.

CHROMIUM

Chrome ore was first produced in the Transvaal about the year 1924. Stratiform segregations of chromitite or chromite rock have a very wide distribution in the lower part of the norite zone of the Bushveld igneous complex. The chromite seams can generally be referred to two or more horizons, and such chromite horizons have been traced in the Lydenburg and Rustenburg districts for scores of miles. Immense reserves of the mineral are thus available. (Figure 12.)

The seams range in thickness from an inch and less to 6 feet. Some of them have been proved to be continuous over stretches of several miles. Others are lenticular and do not persist for any great distance along the strike. The chromitite seams conform strictly to the pseudo-stratification of the rocks of the norite zone. The dips of the seams range from 5° to 30° . The chromitite has, as a rule, a peculiar mottled appearance and consists of pseudo-phenocrysts of bronzite, crowded with minute inclusions of chromite set in a base composed of larger chromite crystals. In addition to the minerals named, subordinate amounts of calcic feldspar and diallage are present.

The chromic oxide content of the chromitite ranges from 28 to 49 per cent., the average being somewhere in the neighbourhood of 40 per cent. The biggest and richest

deposits are in the Lydenburg district, where the chromite rock is at present being mined on the farms Mooihoek 147 and Grootboom 186. The ore averages between 42 and 46 per cent. of Cr_2O_3 . In the Rustenburg district the average grade is between 35 and 42 per cent. of Cr_2O_3 .

A feature of the Bushveld chromite which distinguishes it from the Rhodesian is its richness in ferrous oxide of which it contains from 24 to 28 per cent.

Less important chromite deposits occur in association with the ancient ultrabasic rocks of the Swaziland system in the northern Transvaal.

MINING¹

Mining is being done on the farms Boekenhoutfontein in the Rustenburg District and on Grootboom, Winterveld and Mooihoek in Lydenburg.

Open-casting has been done down to a depth of 9 feet at Boekenhoutfontein, where the ore-body averages 30 inches in thickness with a regular dip of 9° SE. From there down to water-level the pillar and stall system has been adopted, and the ore broken by light blasts. The hanging is treacherous and the drives are close timbered. In the Lydenburg district much ore is obtained from surface debris. The seams are from 4 to 12 feet thick and very regular. The deposits are opened up by adits and mined by the pillar and stall system, the excavated ground being in some cases filled by debris from the hillside.

In mining the ore comes away very cleanly and a certain amount of hand sorting and screening has been found sufficient to produce a saleable product averaging from 40 to 44 per cent. Cr_2O_3 , with a silica content of less than 5 per cent.

Chromium is used as an alloy, ferro chrome, for hardening steel, the final steel product containing from 1 to 5 per cent. of chromium. It is used for refractory furnace linings and as bichromate for the manufacture of paints, etc. The high commercial grades of chrome ore range from 45 to 55 per cent. of Cr_2O_3 but under modern conditions ores of lower grade are utilized.

The ore produced in the Transvaal since 1924 is as follows:—

1924	...	...	...	...	2,056 tons
1925	...	...	...	...	12,474 "
1926	...	...	...	...	14,980 "
1927	...	...	...	...	16,983 "
1928	...	...	...	...	31,327 "

¹ Contributed by J. Thorlund, Mining Engineer, Johannesburg.

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The total value of chrome ore produced in the Union up to the end of 1928 is £98,782.

COBALT

Cobalt was one of the first metals mined after the European occupation of the Transvaal. In the eighties of last century a good deal of rich picked ore was sent to Europe from the old cobalt mine on the farm Kruis River in the northern part of the Middelburg district, Transvaal. Here cobalt in the form of smaltite and its alteration products, erythrite and transvaalite, occur in narrow replacement veins following the bedding of a dense pink feldspathic quartzite, belonging to the Rooiberg Series, immediately below its contact with a thick sheet of gabbrodolerite. The latter is probably connected with the norite zone of the Bushveld complex exposed a short distance to the north. The veins which parallel the contact dip to the south at 60°.

According to Molengraaff smaltite, associated with molybdenite and chalcopyrite, occurs in narrow lodes in the norite of the Bushveld complex, on the farm Laatse Drift 82, three miles west of the Kruis River lode.

Workable lode deposits of cobalt were also opened up about 20 years ago on the farm Eenzaamheid, situated two miles south of Balmoral Station on the Pretoria-Lourenço Marques Railway. These lodes, according to Mellor and Beck, are mineralized dykes in altered sedimentary rocks, the dykes being connected with a big neighbouring mass of basic igneous rocks. The cobalt minerals are smaltite and cobaltite, with which in one of the lodes a good deal of niccolite is associated. At the outcrop the primary cobalt minerals are replaced by erythrite.

Small deposits of cobalt are also present in some of the mineral deposits in the central part of the Bushveld igneous complex.

There are no official returns in regard to cobalt production in the Union.

LEAD

Before the introduction of breech-loading arms, lead for bullets was smelted in the Transvaal. After the introduction of fixed ammunition this was discontinued.

Lead was mined at Argent in the Transvaal between 1889 and 1893 and a smelting works was erected there at about that time. These deposits were again worked between 1922 and 1925, but have shut down since.

In recent years the total production of lead has been small, and has been derived from the Marico district of the Transvaal, the Edendale lead mine near Pretoria, and the Ballock lead mine in the Hay district of the Cape Province. (Figure 12.)

ORE-BODIES

Two main types of occurrence may be distinguished, namely:—

1. Irregular replacements in the dolomite series of the Transvaal system.
2. Vein or lode deposits.

Replacement Deposits

The most important deposits of this nature are situated in the Marico District of the Transvaal where there is a fairly well-defined lead belt, 45 miles in length, following the uppermost horizons of the dolomite between Klaarstroom 55 and Bokkral 300, situated respectively 7 miles west of and 30 miles south-east of Zeerust. This belt also contains important deposits of zincblende, fluorspar and vanadinite. It is evident therefore that the contact between the dolomite and the impervious overlying shales of the Pretoria series provided in this area favourable conditions for the circulation of mineral bearing solutions.

It should be stated that within the tract of country under description the rocks of the Dolomite and Pretoria series dip at low angles to the north or north-east or are disposed in gentle undulations, the dolomite often lying quite flat.

The rocks of both series have throughout the area been intensely metamorphosed as a result of the contact action of the Bushveld complex. The commonest contact mineral in the dolomite is tremolite, occurring in acicular crystals and stellate aggregates of such crystals. Talc is, however, also very common and appears in certain areas to take the place of tremolite.

The lead deposits present much the same features. They are, as stated, irregular replacements in dolomite or more correctly in soft brownish-black manganese earth which over wide areas have completely replaced the uppermost horizons of the dolomite, this manganese replacement which took place long subsequent to the formation of the lead deposits having clearly proceeded from fissures traversing the dolomite. The lead deposits are as a rule made up of a succession of irregular nodular

masses or disseminations of galena or of secondary minerals derived from it. These include cerussite, minium, massicot, pyromorphite and vanadinite. The galena is often accompanied by zincblende. That the galena has developed by the replacement of dolomite is proved by the fact that the original bedding planes of that rock are often clearly discernible on the surfaces of the nodular masses. These range in weight from a few grammes to several tons. The most important deposit is that of the Doornhoek mine on Doornhoek 32, which has been worked intermittently since the seventies of last century, and is estimated to have yielded altogether some 7,000 tons of galena, the latter containing from 5 to 8 ounces of silver per ton. The galena occurs in the usual nodular masses lying in the soft manganese earth, previously referred to, which here occupies an irregular area lying between two well-defined zones of fissures some 250 yards apart and striking approximately north and south. The galena nodules occur in fairly well-defined layers following the original bedding of the replaced dolomite. The manganese earth in places carries notable amounts of cerussite and vanadinite, containing up to 1.15 per cent. of V_2O_5 . In that part of the mine east of the easterly bounding fissure, galena in irregular masses, up to 20 inches across, associated with fluorspar and talc occurs in unreplaced dolomite. The galena occurs along the bedding planes of the dolomite near fissures traversing that rock. This part of the mine gives a good idea of what the main portion of the occurrence was like prior to the replacement of the dolomite by manganese earth.

Lode Deposits

Under this head reference may first be made to the occurrences on the farms Dwarsfontein 143, and Brakfontein 219, situated near Argent Station on the Johannesburg-Witbank Railway, some 50 miles east of Johannesburg. They are the most productive silver-lead deposits so far discovered in South Africa. They were worked on a big scale between 1889 and 1893, and again between 1922 and 1925 by the Transvaal Silver and Base Metals Company, Ltd. On these farms norite and pyroxenite belonging to a small offshoot from the Bushveld complex are intersected by a series of parallel fissure veins striking 50° west of north. The most important is a so-called main lode on Dwarsfontein which can be traced on the surface for over 5,000 feet. It dips south-west at

from 45° to 80°. The thickness of the vein varies from 14 feet to nothing, the deposit giving out altogether in places. The primary ore minerals are galena, argentite, native silver, chalcopyrite, pyrite, pyrrhotite and zincblende. The gangue minerals include siderite (sideroplesite) quartz, chlorite, and dolomite. Argentite occurs as minute microscopic inclusions in the galena which are only rendered visible by etching polished surfaces of the mineral with nitric acid. The galena contains roughly one ounce of silver to every one per cent. of lead.

The vein matter is, as a rule, roughly banded parallel to the vein walls, being made up of alternations of galena and siderite-rich bands through which isolated patches of chalcopyrite are scattered. The last-named becomes increasingly abundant at depth. The workable ore occurs in irregular patches surrounded by barren siderite. The distance between the individual patches was found to increase with depth, and at an average depth of about 500 feet the vein was no longer workable. The other lodes are similar in character. The ore of the Brakfontein vein is, however, much richer in brown zincblende of which it contains an average of 10 per cent.

There are similar lodes on the farms Spitzkop 407, and Hartebeestfontein 398, situated 12 miles north-east of these occurrences.

Closely related to these galena-siderite veins is the vein at one time worked at the Edendale lead mine, situated on the farm of that name 17 miles north-east of Pretoria. The ore minerals are galena and zincblende with chalcopyrite appearing at depth as in the Brakfontein vein. The mine has been worked at different times from 1904 to 1908 when moderate amounts of both galena and zincblende were produced, and intermittently from 1923 until the present time.

All these veins are clearly related genetically to the Bushveld igneous complex.

During the period 1917-1920 notable amounts of galena were recovered from a vein in the Waterberg sandstone on the farm Windhuk situated in the Blaauwberg in the Zoutpansberg district of the Transvaal.

At the Balloch mine, situated 38 miles north of Prieska in Griqualand West, there is being worked a series of parallel veins carrying galena accompanied by subordinate amounts of zincblende in a gangue of quartz and ankerite.

The production of lead in the Union for the last few years is as follows: 1926, 374-746 tons; 1927, 452-232 tons;

1928, 42,320 tons; and about 54 tons in 1929. The total value of lead produced in the Union up to the end of 1928 is returned as £574,975.

MANGANESE¹

Small deposits of manganese were worked in the Cape Province many years ago and others occur in the Transvaal, but none of these has proved of economic importance. In 1922 manganese was found outcropping over a wide stretch of country near Postmasburg about 108 miles west-north-west of Kimberley. The Postmasburg deposits contain a very large reserve of manganese ore which will suffice to supply the requirements of the country for many years. They are being developed and a railway built to facilitate their transport. (Figure 12 and Plate XXVII.)

The manganese is found (a) along the Gamagara range of hills, (b) in a series of detached hills comprising the Klipfontein range, and (c) on some prominent solitary kopjes or low rises which are outliers of the rocks building the main ridges. Of these occurrences the last mentioned are only small irregular patches of ore, far apart, and of little economic importance. The most important deposits are those of the Gamagara and Klipfontein hills; in other words, the deposits occur chiefly within two belts of country roughly parallel to one another and conveniently referred to as the western or Gamagara and the eastern or Klipfontein belts.

ORE-BODIES

There are two principal varieties of ore in the Postmasburg area, one massive or non-crystalline, the other crystalline. These may occur separately, but generally they are intimately associated with one another in various degrees of admixture without any sharp line of separation. The massive type agrees in composition and properties with psilomelane; the crystalline ore on the other hand consists of a mixture of two or more of the manganese minerals such as braunite, manganite, and sitaparite. The ores are closely associated with hematite, other iron oxides, quartz and chert.

In the western belt manganese ore has been proved to be present along the whole length of the Gamagara ridge, a distance of about 38 miles. The ridge is built of quartzite, highly aluminous flagstones and shale, and, along the base

¹ Contributed by L. T. Nel, Geologist, Geological Survey of the Union of South Africa.

N.W.

S.E.

Gamagara Ridge



FIGURE 18

0 200 400 600 800 Yards

Section across the Gamagara Ridge north of Postmasburg, to show occurrence of Manganese ores, and folding of the Gamagara Beds.

1 Dolomitic limestones. 2 Manganese ore associated with patches of ferruginous sedimentary breccia, or basal conglomerates. 3 Shale band. 4 Quartzites.

[After L. T. Nel.]

of the sequence, lenticular bodies of a coarse ferruginous sedimentary breccia or conglomerate. These beds have been termed the Gamagara series and are correlated with the Matsap series (Waterberg system). They generally dip from about 10 to 20 degrees in a westerly direction and rest unconformably on the Campbell Rand and Griquatown series which embrace a large group of dolomitic limestones, volcanic beds, banded jaspers, chert, ironstones, shales, a tillite, two or three small quartzites and the peculiar Blink Klip breccia.

The ore is found along or close to the line of unconformity and is generally associated with the basal members of the Gamagara series. With the partial denudation of these beds extensive masses of ore were laid bare which are distributed over the hill slopes, the inclination of which conforms to the westerly dip of the Gamagara series. The average thickness of the ore-body over a great length of strike is very difficult to ascertain. Prospecting trenches and pits, however, have shown that the ore varies from less than 3 to over 20 feet in thickness.

A few miles farther east the Klipfontein line of more or less detached hills and ridges rises abruptly from the level dolomite plains. Along this hilly tract of country the presence of manganese has also been proved. It is referred to as the Eastern belt. The high ground is largely built of the resistant Blink Klip breccia. This dark ferruginous rock, with the evidence of folding, crumpling and brecciation plainly visible, rests on gently inclined Campbell Rand dolomitic limestones. As this structure is the result of subsidences and settling of the lower Griquatown beds into great solution cavities in the underlying limestones, the trace of the contact between these formations on a vertical plane is a tortuous line passing across different horizons of the limestone. The manganese ore is located along or close to this irregular contact so that its distribution is thus closely connected with a highly disturbed zone characterized by corrugated and brecciated rocks.

In the mode of occurrence and distribution of the ore deposits within the western and eastern belts there are important differences which may be briefly stated as follows:—

(1) The form of the manganese deposits of the western belt is in general that of a sheet, and it tends to form continuous outcrops extending for many hundreds and even thousands of yards. The eastern belt is largely characterized

by vertical, highly irregular ore-bodies of relatively small lateral extent, which are detached and occur at irregular intervals.

(2) In the western belt manganese ore is associated with a sequence of rocks of different geological age from that in the eastern belt. The manganese deposits of the two belts are, therefore, not circumdenuded outliers of a former ore sheet of regional extent.

QUALITY OF THE ORE

Most of the manganese produced at the present time is used in the form of an alloy in steel making, a manganese content of about 40 lb. of high-grade ore being contained in a ton of average steel. To produce the high-grade alloy, ferro-manganese, for steel making, an ore of a minimum content of 35 per cent. manganese and one that will carry not more than about 10 per cent. of iron and 15 per cent. of silica is required. As yet one is unable to determine with any degree of accuracy the average manganese and iron contents in the ore over the whole length of either the western or eastern belts, but according to a large number of partial and complete analyses the average figure for metallic manganese will probably be between 40 and 50 per cent., while that of iron will probably exceed 7 per cent. though it is not likely that it will be more than 14 per cent. At the same time it has been proved that there are extensive deposits yielding ferro-grade ore with less than 10 per cent. of iron. The alumina content varies from 0 to 19 per cent., sulphur, 0.15 to 0.75, and phosphorus 0.02 to 0.15. The manganese occurs in conjunction with large deposits of ferruginous manganese, manganiferous iron and hematite ores, so that the quality of the manganese ore, which is practically free from other harmful ingredients depends largely on the iron content. It has already been proved that ore suitable for the production of ferro-manganese can be readily sorted, in practice, from ore of inferior grade, so that there should be no difficulty in maintaining an output of a high-grade product.

The ore possesses superior physical qualities which prevent any crumbling or production of fines during mining operations, ensure very little loss in transit, and reduce loss from flue dust to a minimum. The ore is also suitable for storage as no tendency is apparent for it to disintegrate.

DEVELOPMENT.

A large tonnage of ore can be mined open-cast or at very shallow depths and the costs of breaking should be low. A railway is being built to the deposits.

The Manganese Corporation Limited,² which has acquired the Union Manganese Company, owns the majority of the farms covering the manganese deposit in the western belt.

Active development has been started on the farm Beeshoek, near the southern end of the range, which will be the terminus of the branch railway line from Postmasburg. Here a crushing, grading and loading plant is erected, and a narrow gauge line will be built to the north to tap the remainder of the deposits along this belt. Many thousand tons of ore have already been quarried and stacked at surface ready to be crushed, sorted and loaded as soon as the railway reaches Beeshoek and is available for traffic.

Outside of the Postmasburg ores the total manganese ore produced in the Union up to the end of 1928 is valued at £9,920, most of which came from the Transvaal. The last year for which returns are available is 1927, in which 300.5 tons were produced.

Judging from the extensive outcrops of manganese ore, in the Postmasburg area and the evidence afforded by many prospecting pits and trenches, the available tonnage of manganese ore is enormous and must run into many millions of tons. Moreover, a large tonnage of this is of ferro-grade ore quality. The bulk of the ore reserve lies in the western belt.

MERCURY

At Hectorspruit situated south of Malelane Station on the Pretoria-Lourenço Marques Railway, cinnabar accompanied by metacinnabarite is disseminated through a belt of crushed quartzite from 4 to 5 feet wide which can be traced at the surface for 400 yards. The quartzite belongs to the Moodies series. The deposit was opened up some years ago and was found in places to average between 2 and 3 per cent. of mercury. Adits driven into the hillside beneath the outcrop failed to locate the deposit. The mineralization thus evidently does not persist to any depth.

² Contributed by J. A. Woodburn, Consulting Mining Engineer, Johannesburg.

MOLYBDENUM

Molybdenite occurs in association with cassiterite in a number of the tin deposits of the Bushveld complex. The most important occurrence is on Groenvlei 610, in the Waterberg tin fields. Here molybdenite is accompanied by notable amounts of bright yellow molybdenum ochre.

Molybdenite was also much in evidence in the "B 6" pipe on Stavoren 1871, from which $3\frac{1}{2}$ tons of 15 per cent. molybdenum ore were recovered in 1915.

In Impendhile County, Natal, molybdenite accompanied by molybdenum ochre and the rare mineral ilsemanite occurs disseminated through coarse sandstone belonging to the Molteno division of the Stormberg series, Karroo system.

The deposit has no economic significance.

NICKEL

The Union possesses large and varied resources of nickel ores. Hitherto there has been no output of the metal, but it promises to become a valuable by-product of the Bushveld platinum industry.

DEPOSITS OF THE BUSHVELD IGNEOUS COMPLEX

The biggest deposits unquestionably are those on the Merensky platinum horizon. Here, as previously pointed out, nickel occurs as pentlandite in association with chalcopyrite and pyrrhotite. The horizon has been traced for hundreds of miles, and the available reserve of low-grade ore on it is practically unlimited. The average nickel content is only about 0.2 per cent. Tests have proved, however, that the bulk of the metal can be recovered by flotation, and as this class of platinum ore is to be worked on a huge scale, there can be no question that large amounts of nickel will be recovered.

Of a somewhat different nature are the nickel deposits occurring in the norite zone of the Bushveld complex on the farm Vlakfontein 902, situated west of the Pilandsberg in the Rustenburg district of the Transvaal. They take the form of isolated masses of irregular shape composed partly of disseminated, partly of poikilitic, and partly of solid sulphide ore, the country rock being bronzitite.

The principal ore minerals are pyrrhotite, pentlandite, and chalcopyrite. At and immediately below water-level the pyrrhotite has been largely replaced by marcasite, which forms perfect pseudomorphs after it. The ores contain notable amounts of gold and traces of platinum metals.

THE MAGMATIC NICKEL-COPPER DEPOSITS OF INSIZWA AND TABANKULU, IN GRIQUALAND EAST

These deposits well known through the writings of Du Toit and Goodchild, occur near the lower contacts of great basin-shaped masses of gabbro-norite—a special phase of the well-known Karroo dolerite—which have been shown to be the remnants of a vast sill intrusive in the lower division of the Beaufort series of the Karroo system. The individual gabbro masses which build prominent bush-clad ranges show pronounced density stratification. They range in composition from gabbro with interstitial micropegmatite at the top through olivine-gabbro and norite to picrite at the bottom. The lowest layer of all is gabbro, evidently a chilled contact phase of the parent magma.

The nickel-copper minerals are associated with the picrite. In the Insizwa deposits both disseminated sulphide ore and massive sulphide ore are present. The former occurs as a big sheet-like body, the latter in veins, stringers and fairly extensive bodies of tabular shape. The disseminated sulphide ore is estimated by Du Toit to contain from 2.5 to 3.5 per cent. of nickel plus copper, the two metals being present in approximately equal proportions. The ore minerals are pyrrhotite, chalmersite, pentlandite, and chalcopyrite, with smaller amounts of bornite, niccolite and zincblende. Subordinate amounts of the platinum metals—mainly palladium—are also present.

In the neighbouring gabbro-norite mass building the Tabankulu Range, smaller ore occurrences of the same type have been located.

OCCURRENCE IN THE BARBERTON DISTRICT, TRANSVAAL

A very interesting nickel deposit was discovered in 1919 on the property of the Scotia Tale Company in the Barberton district, Transvaal. It takes the form of a tabular ore-body 2 feet thick in green talcose schist. This contains where sampled from 17.2 to 25.8 per cent. of nickel. The metal is present in the form of trevorite, a mineral new to science. It is a magnetic nickel-iron oxide belonging to the magnetite group, and having the composition NiFe_2O_4 .

Occurrence on Blaauwbank 433, Waterberg district. On this farm, situated about 4 miles west of the main workings of the Rooiberg tin mine, there outcrops a flat-dipping fissure vein ranging from 2 inches to 6 feet in thickness which carries notable amounts of nickel. Near the surface

that metal is present in the form of solid masses of nickelbloom (annabergite) up to 2 feet in thickness. At depth this gives place to patches of niccolite and gersdorffite embedded in a gangue of ankerite. The ore carries some gold.

RADIUM AND URANIUM

A series of pegmatite veins carrying uraninite in crystals and nodular masses up to several inches across are found on the farm Bokspuits, in the valley of the Back River 6 miles from the Orange River in the Gordonia district, Cape Province. They were prospected in 1927 and 1928, but work ceased in February, 1929.

ZINC

Zincblende, as previously stated, occurs in association with galena in many of the deposits of the Marico lead belt. (Figure 12.) In some of these occurrences it is the predominant mineral and two of them have actually been worked as zinc mines. They are the deposits on the farms Witkop 288 and Buffelshoek 284. They both take the form of remarkable pipes giving rise at the surface to circular outcrops comparable with the zinc "circles" of the Joplin District of the United States.

The Witkop pipe, which is the more important, measures 170 feet from north to south and 160 feet from east to west. It is surrounded by an annular zone of tremolite rock which forms a ring-shaped ridge projecting from two to three feet above the surrounding country. This tremolite-rock zone merges outward into less and less tremolitized dolomite, which is here horizontal and quite undisturbed. The maximum alteration of the dolomite thus clearly took place adjacent to the pipe. The deposit is vertical and has the shape of a truncated cone, the diameter increasing gradually with increasing depth down to 280 feet, the greatest depth reached. The interior of the pipe is occupied for the most part by a coarse breccia composed of blocks of dolomite and shale cemented by calcite, fluorspar, and quartz. Zincblende associated with the three gangue minerals named and with subordinate galena and pyrite, follows the outer circumference of the pipe as an annular vein of varying width, which throws off occasional branch veins toward the centre of the occurrence, some of the branch veins opening out into large irregular ore chambers in the breccia already referred to.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

In the Buffelshoek Pipe tale largely takes the place of tremolite and zincblende, instead of forming an annular zone it is fairly uniformly distributed through the pipe filling. Fluorspar is abundant, and the pipe thus forms a connecting link with the fluorspar pipe on the farm Oog van Malmani, which is situated a few miles to the south.

The value of the zinc produced in the Union up to the end of 1928 is given at £50,998, all of which came from the Transvaal.

TUNGSTEN

Scheelite occurs in considerable quantities in some of the tin deposits on the farm Stavoren 1871 in the Waterberg district, Transvaal. During the Great War some 30 tons of mineral were recovered, but owing to the big drop in the price of tungsten immediately after the cessation of hostilities, its recovery was abandoned.

Wolframite occurs in association with cassiterite in the deposits on Mutue Fides 1844, Groenvlei 610, and Appingadam 1870 in the Waterberg District; also in quartz lodes on the farms Langverwacht and Hazendal situated 18 miles west of Cape Town.

VANADIUM

Vanadinite, the chloro-phosphate of vanadium, occurs in association with lead ores at various localities in the Transvaal. The most extensive deposits so far opened up are situated on the farm Kafferskraal 214, 15 miles south-south-east of Zeerust in the Marico district, Transvaal. Here vanadinite in well formed hexagonal crystals occurs in the uppermost portion of the dolomite series in irregular layers following the bedding of soft manganese earth that has here replaced the dolomite. The mineral also occurs in steeply dipping stringers cutting across the bedding of the manganese earth, and in irregular pockets and as an incrustation of joint planes. It is clearly of supergene origin, its lead content having been derived from galena. In places are found irregular nodules showing a kernel of galena surrounded by concentric layers of pyromorphite and vanadinite, the vanadinite encrusting the pyromorphite.

Attempts at concentrating the vanadinite on a large scale have so far failed. In 1923, 54 tons of concentrate carrying 7 per cent of vanadium were produced.

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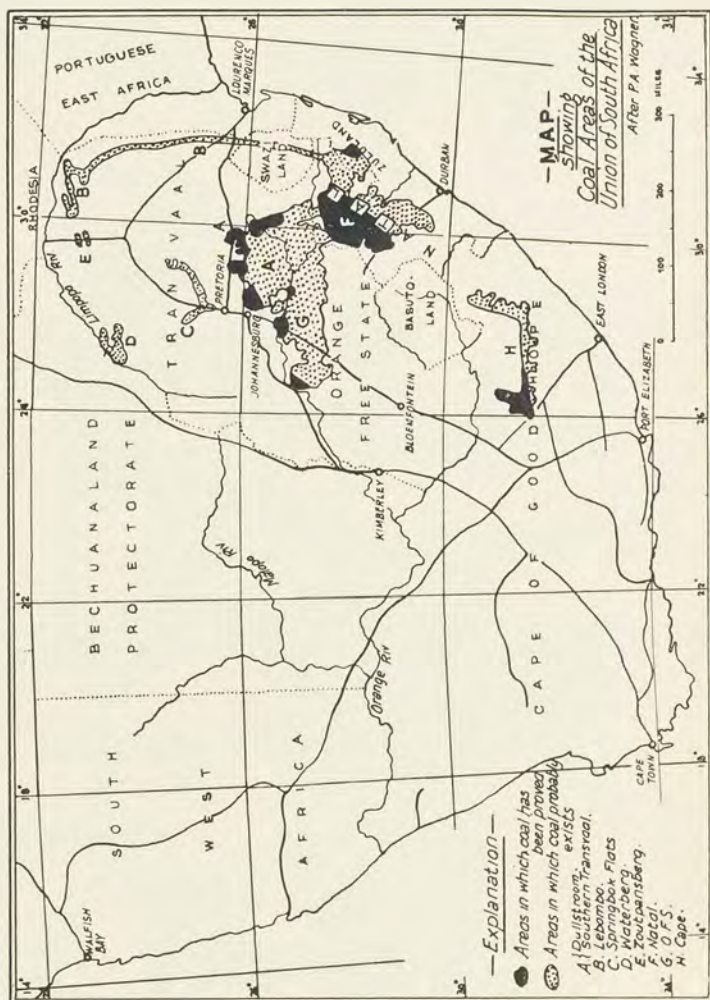


FIGURE 19.

CHAPTER VIII

COAL AND OTHER FUELS.

COAL

By T. COULTER¹

HISTORICAL

There is evidence that coal was used in ancient times in South Africa, for old slag heaps near ancient workings in Zululand have been found to contain coal. There is no doubt also that the natives used coal more recently for the smelting operations in connection with the manufacture of their fighting weapons and agricultural implements.

Coal was first discovered by Europeans in Natal about the year 1840. In 1852 a prize of £100 was offered for the discovery of coal "sufficiently near Capetown to be cheaper than importing it." It is recorded that very thin deposits of lignite and coaly shale were at that time discovered in the Cape Flats, but they were commercially of no value. In 1859 coal was discovered at Cyfergat in the north-eastern part of the Cape Province, and in 1864 a colliery was started close to Molteno, and coal was discovered soon after at Indwe, 70 miles east of that place.

The serious mining of coal was started in the Indwe-Molteno district a few years later, when the opening of the diamond mines at Kimberley created a demand for fuel in large quantities. At this stage the Indwe and Molteno collieries were connected by rail to the main East London line. In 1885 the collieries at Cyfergat and Molteno produced 16,483 tons. Later discoveries of better coal in Natal and the Transvaal gave this field a severe setback. The production from Cape Province in 1928 was only 5,059 tons.

Although coal was discovered in Natal in 1840, it was not until the late eighties that any attempt was made to open up the deposits on a commercial basis. In 1881 F. W. North was appointed by the Natal Government to investigate and report on the coal occurrences. As a result of his investigation the Government introduced diamond drills for proving the fields.

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MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

In 1889 seven collieries were at work in Natal with an output of 28,682 tons. Since that date the output for Natal has shown a continual rise, and close on five million tons were sold in 1928.

In the Transvaal, coal was discovered by the Dutch settlers soon after they first arrived in the country, but it was not until the discovery of gold on the Witwatersrand in 1886 that there was sufficient demand to justify the opening of the seams. As stated in Chapter IV., the first coal used on the Rand came from Steenkoolspruit, from Boksburg and Springs.

In the year 1879 coal was discovered in the Vereeniging district by Stowe, and was first transported to the diamond mines at Kimberley. The growth of the Witwatersrand gold field caused the expansion of the Vereeniging field and the opening of the Witbank coal field in the late nineties.

The outputs from the four provinces of the Union for the year 1928 were as follows:—Cape, 5,059 tons; Natal, 4,641,145 tons; Transvaal, 7,669,102 tons; and the Orange Free State, 1,088,109 tons. A total of 13,403,415 tons, valued at £3,672,966 at pit's mouth, equivalent to an average value of 5s. 6d. per ton.

The total value of the coal output of the Union from the earliest date of existing records to December 31, 1928, is as follows:—

Transvaal	...	...	...	...	£40,544,397
Natal	...	...	...	...	32,807,897
Orange Free State	...	...	...	...	4,910,835
Cape	...	...	...	...	2,022,043
Total	...	...	...	...	£80,285,172

DISTRIBUTION

The areas under which coal appears to have been proven to date are shown in Figure 19. The limits of areas under which there is good reason to believe that workable coal seams exist have also been indicated.

The total number of producing collieries in the Union for the year ended 1928 was 70, of which Natal had 32, Transvaal 31, Cape Province 5 and Orange Free State 2.

Coal is mined for export from 24 collieries lying within an area of 2,000 square miles, in the districts of Klipriver, Newcastle, Utrecht and Vryheid in the northern parts of Natal, and from the Middelburg and Breyten areas in the Transvaal.

Other proven fields lie in Zululand, in the country between Ermelo and Carolina, Middelburg and Belfast, and in the Bethal district in the Transvaal; north-east of Kroonstad in the Free State, and between Aliwal North, Woodhouse and Molteno in the Cape Province.

The distance by rail from the centre of the Natal coal fields to the port of Durban is 275 miles. From the centre of the Witbank coalfield to the port of Lourenco Marques in Portuguese East Africa is 276 miles. The distance from the Witbank coalfield to Capetown is 1,045 miles.

The coal areas of the Union are very large in extent, and are situated in every case in the interior of the country. Coal of commercial value has not yet been proven at any point in close proximity to the coast.

GEOLOGY.

The chief deposits of coal in the Union are contained in the coal measures of the middle Ecca series of the Karroo system (see Chapter I). The lower and upper portion of the series are practically barren of coal.

Coal measures of the middle Ecca vary in thickness from 300 feet in the south of Natal to close on 1,200 feet at Dundee, in the centre of the Klipriver coal field. In the Witbank coal field, the thickness does not exceed 400 feet, and in this locality the lower Ecca measures are missing, the coal measures resting directly on the Dwyka conglomerate.

The coal seams of the Cape Province occur in the Beaufort and Stormberg beds of the Karroo system, which lie above the Ecca series. Bands of lignite are occasionally to be found in the Cretaceous and Tertiary beds in the south-eastern portion of the Cape Province, but these are apparently not of economic importance.

COAL MEASURES OF THE ECCA SERIES

The coal measures are made up of sediments of every degree of coarseness from conglomerates to shales, with a predominance of sandstones and grits. Over considerable areas beds of iron ore are in places intercalated with these rocks. The coal-bearing beds are for the most part disposed horizontally, or nearly so, and are in many places intruded by dykes and sheets of dolerite. The coal has a characteristically banded appearance, being made up of alternations of thin layers of bright coal, clarain and vitrain, and dull coal, fusain and shaly matter. A great proportion of these coals may be classed as "bituminous" and rather high in ash.

The best quality coals are found in Natal. Next in order comes the Transvaal, then the Orange Free State and lastly the Cape.

Generally speaking, the seams that are being worked are thinner in Natal than in the Transvaal or Orange Free State. The sulphur content of the coals now being mined is not excessive, averaging slightly more than 1 per cent. The sulphur, moreover, occurs in a form which can easily be removed by washing.

The physical condition under which the coal was deposited appears to have differed somewhat from that under which many of the better known coal seams in other parts of the world were laid down. This applies particularly to the Transvaal area, where the coal was apparently not deposited in vast swamps or marshes, but in more or less isolated basins with uneven floors on the margins of which ridges of older rocks rose abruptly, in some instances to a height of 200 feet above the general level.

In the Witbank coal field the bottom seam of the series has been deposited practically on top of a glacial conglomerate over considerable areas.

The common absence of "underclays" below the coal beds, and the frequent presence of shaly or even sandy bands in the coal seams, led to the belief that all South African coals were of drift origin. This view, however, is negatived by the occasional occurrences in connection with some of the coals of the stumps and roots of large coal measure plants in the positions in which they grew, and also by the persistent character of some of the seams, which contain a comparatively low percentage of foreign matter.

COAL MEASURES OF THE STORMBERG SERIES

In the Cape Province workable seams of coal are confined to the Molteno beds of the Stormberg series, which occur towards the top of the Karroo system. The seams appear at intervals along a belt of country extending from Aliwal North to Molteno, and from there eastward through the Transkei, towards Natal. They occur on three well-defined horizons, known as the Indwe, Guba and Molteno seams, of which the first and third are the most important. The seams consist of alternating layers of shale and coal, the thickness of a single layer of coal rarely exceeding 2 feet. As a rule the seams are thin, although they attain a thickness of from 10 to 12 feet in places, but in these

cases the proportion of shale is very high. The coal is generally of poor quality, with a rather high ash content in most places.

In the following description the chief coal fields of the Union are classified according to the provinces in which they occur, and the provinces arranged in the order of their output. These will be dealt with in the order given.

TRANSVAAL

The Transvaal coal fields are the most extensive, and embrace five separate areas, namely:—

- (a) The Highveld or southern Transvaal area.
- (b) The Bushveld area.
- (c) The Lebombo area.
- (d) The Limpopo area.
- (e) The northern Waterberg area.

Of the foregoing only the Highveld or southern Transvaal area is at present being exploited. It includes a number of separate areas, namely:—

Witbank Area

This is the most important producing field in the Union, and is responsible for 40 per cent. of the total output at the present time. It occupies a considerable portion of the southern section of the Witbank district, including the Steenkoolspruit area with an extension towards the district of Bethal, together with a large undeveloped area in the district of Middelburg, some 20 miles to the east. The coal measures lie practically flat, and vary in thickness from 50 to 400 feet, with an average of about 200 feet.

There are five distinct seams which are numbered from the bottom up. The No. 1 seam is known throughout the area as the Bottom seam and the No. 2 seam as the Main seam. These two produce practically the entire output from the Witbank district, with only a very small proportion from No. 4. No work is at present being done on Nos. 3 and 5. In certain localities the five seams have an aggregate thickness of close on 60 feet of coal. Of this total the average thickness worked is 10 feet, and ranges from 4 to 15 feet in different mines. (Figure 20.)

The No. 1 or Bottom seam ranges from 4 to 10 feet in thickness, and is a bituminous coal eminently suitable for steam-raising purposes. It contains about 25 per cent. volatile matter and 10 per cent. of ash, with a calorific value² averaging about 13·25. Generally speaking, it is a non-coking coal.

² The unit of calorific value is the number of pounds of water that can be turned into steam by one pound of coal.

The No. 2 or Main seam furnishes the greater proportion of coal produced on the field. In places it reaches 23 feet in thickness, but only the lower part contains coal of the standard required by the present-day market. This portion contains coal of a laminated nature, whereas the coal from the upper portion is massive. The portion mined ranges from 4 to 15 feet in thickness, and the coal produced contains from 11 to 15 per cent. of ash with a calorific value averaging about 13·00. In places the lower portion of the seam is exceptionally bright, and it is from this bright coal that good quality coke can be produced on several collieries. On the whole the Main seam is a hard, mixed dull and bright steam coal, which stands handling and transportation extremely well.

The distance from the centre of the Witbank coal field to Johannesburg is 100 miles.

There are 13 collieries operating at present in this area, and the total coal sold for the year 1928 amounted to 5,311,333 tons.

Ermelo-Carolina Area

This area is situated in the Ermelo district and in the adjacent portion of the Carolina district. There are two seams, of which the lower contains coal of good quality averaging slightly under 6 feet in thickness. The coal mined has a calorific value slightly over 12, and from 28 to 29 per cent. of volatiles, of the same character, but of a slightly lower grade than at Witbank. There are 6 collieries at work, including one small anthracite concern, the output of bituminous coal for the year 1928 was 1,018,732 tons.

Springs Area

This area is situated at the extreme eastern end of the Witwatersrand, and although it is of small extent and contains coal of relatively poor quality, it is of great industrial importance owing to its proximity to the Witwatersrand. The area contains three workable seams, namely, the Top, Middle and Bottom. The Bottom seam may be correlated with the Main seam of the Witbank area, while the Middle and Top seams may be correlated with the Nos. 4 and 5 seams of the Witbank area.

Mining is now taking place on the Top and Bottom seams. The average calorific value of the coal now being won from this area varies from 9 to 11·25, and volatiles 21 to 22 per cent.

There are three producing collieries with a sales output for the year 1928 of 1,127,565 tons. The greater proportion of this tonnage is used in the Victoria Falls and Transvaal Power Company's stations on the Witwatersrand.

Heidelberg Area

Only one colliery is producing in this area, the output for the year 1928 being 158,078 tons.

Nigel Area

This area is situated about 25 miles south of the Witwatersrand, and contains three small areas of coal of inferior quality, only one of which was worked for a short time. This area is probably of no economic importance.

Vischkuil-Delmas Area

This area is situated about 50 miles east of Johannesburg. It contains three seams, but only the lower part of the Bottom seam is of any value. The coal is of poor quality, and in the localities worked to date did not exceed a calorific value of 10, with volatiles somewhat on the low side.

One colliery operated in this area for a number of years, but has now been closed down.

Belfast Area

This area includes two small outliers of coal measures in the neighbourhood of the town of Belfast. A thick seam of rather poor quality is now being worked at two places for local requirements.

Vereeniging Area

This is a direct continuation northward across the Vaal River of the Orange Free State coal field. Coal was mined here in the 'eighties, and transported to the Kimberley mines by ox-wagon. One small colliery is now operating.

Undeveloped Coal Areas

There are undeveloped coal-bearing areas in the Bethal, Standerton and Wakkerstroom districts of the Transvaal and the Piet Retief district of Natal adjoining Wakkerstroom. About these coals very little is known. Some of the coals in Wakkerstroom and in Piet Retief to the east of it are of high grade. Wybergh has estimated that a large area carrying much coal occurs here and in the Bethal district.

Springbok Flats Area

This is situated about thirty miles north of Pretoria, and occupies an oval-shaped piece of country, measuring roughly

70 miles by 30 miles, with the longer axis trending north-east. Coal seams of considerable thickness have been struck in boreholes, and in one shaft, but the quality appears to be very inferior, and as it is less favourably situated with regard to the principal centres of consumption than the fields already dealt with, there is no prospect of it being worked in the near future.

Between the main Bushveld area and Pretoria is a small outlier of the coal measures, which was at one time worked at the Rogerston Colliery.

The Lebombo Area

This contains a strip of coal measures some six miles wide, which extends along the eastern boundary of the Transvaal and Swaziland for a distance of several hundred miles and then swings round to the west into the northern part of the Zoutpansberg district. Some of the coal may be of fair quality, but much of the coal tested is anthracitic in character, the change to anthracite being doubtless due to heat from the great overlying mass of the Lebombo lavas. The area is referred to as Komatipoort by Wybergh in the table of ore reserves.

Zoutpansberg or Limpopo Area

This includes a number of detached areas south and south-east of Messina in the Zoutpansberg. The coal has so far only been opened up at one locality, named Lilliput. The seam here exposed is 3 feet thick and the coal of rather inferior quality.

Northern Waterberg Area

This is bounded on the north and west by the Limpopo River, on the east by the Pongola River and in the south by an unconformity or fault with an east and west trend passing a little to the north of the Rooibok Hills. Seams have been proven by boring only, as there are no outcrops. Numerous seams were found in some of the boreholes. There are two workable seams of which the lower yields coal of much the same quality as that worked in the southern Transvaal. The few analyses indicate calorific values of from 11 to 13, and volatiles from 18 to 30 per cent. It will probably be a long time before these inaccessible fields are worked.

NATAL AND ZULULAND

The coal fields of Natal and Zululand are of considerable extent. The Klip River and Vryheid coal fields of Natal occur in the northern part of the Province. (Figure 19.)

The Klip River Coal Field

This comprises an area that stretches from Ladysmith north as far as the N'Kandu River at Newcastle, and eastward beyond Dundee as far as the Buffalo River. The centre of this field is Glencoe Junction situated 231 miles by rail from Durban, and 252 miles from Johannesburg.

The commercially valuable seams of the Klip River coal field are only two in number and are generally known as the Top and Bottom seams. Their aggregate thickness varies from 4 to 20 feet, but an average can be taken at from 6 to 10 feet. All classes of coal are found in these two seams, varying in composition from anthracite to gas coals.

An analysis is given under "Quality of coals." The calorific value varies from 13 to 14, and the volatiles from 20 to 30 except where affected by dykes. A striking feature of the Klip River field is the extent to which the coal measures have been invaded by dykes and sills of dolerite. These have often changed the bituminous into more or less anthracitic coal, and in several places into impure coke. At the same time the gas given off has accumulated so as to convert many of the pits into fiery mines, which have to be worked with safety lamps. The average depth of the seams near Glencoe Junction is 500 feet. The quality of coal from the Klip River and Vryheid fields is the best found in South Africa and is in great demand for the bunkering trade in Durban.

The reserves of high-grade coal are relatively small, and will, it is believed, be exhausted within 70 or 80 years at the present rate of output. The reserves of good coking coal are estimated to be in the order of 150 million tons.

The Vryheid Coal Field

This comprises the area east of Vryheid and north as far as Paulpietersburg. The coal is similar to the Klip River coal in quality.

Because of the similarity of the coal measures in the Utrecht district and in the Newcastle district north of the N'Kandu river to those in Vryheid the three areas are grouped together as one field. The coal deposits are not continuous and workable areas, but are scattered over a large stretch of country. They represent the remnants of what must have been originally a huge coal-bearing area, reduced to its present dimensions by erosion. All classes of coal are found in the remaining areas varying in composition from anthracite to rich gas coals. In most

instances the workable areas lie in isolated mountains in which the coal seams are situated several hundreds of feet above the level of the surrounding country. They can therefore be readily developed by adits.

There are four workable seams known as the "Alfred," "Gus," "Dundas" and "Coking" and averaging 5 and $2\frac{1}{2}$ feet in thickness respectively.

The "Gus" Seam is the most important of the four. The coal of this field is on the whole of excellent quality, being low in ash and sulphur. A great proportion is of high-grade coking quality. This field is responsible for 45 per cent. of the present total output from Natal.

Utrecht Coal Field

This comprises all the coal-bearing ground within the magisterial districts of Utrecht and Paulpietersburg. It contains four seams identical with those of the Vryheid field aggregating from 10 to 11 feet of clean coal. The coal varies from bituminous to semi-bituminous and is on the whole of excellent quality. Unfortunately large areas of this field contain anthracitic coal, while the bituminous coal in many parts produces an ash which has a low fusibility causing clinkering. This field has been proved to contain a fair quantity of good coking coal.

The Zululand Field

There are extensive coal-bearing areas in Zululand, but so little systematic work has been done on them that they are at present unknown quantities. Some of the Zululand coals are of Ecca age, but much of these coals are in the lower Beaufort series. A colliery was started over twenty years ago at Somkele, which is situated about 20 miles from the coast and 188 miles north of Durban, but the coal proved to be anthracitic and very dirty, in consequence of which work was discontinued in the early stages of its development.

It should be stated that the Zululand coal field is continuous with the southern part of the Lebombo coal fields previously referred to.

ORANGE FREE STATE

These fields are situated in the northern part of the Orange Free State and are of very great extent, having an area of probably 10,000 square miles, the coal seams varying in number from one to four and their aggregate thickness from 6 to 53 feet. The seams are persistent and uniform in character, but the quality of the coal is

unfortunately uniformly poor, the calorific value ranging from 9·00 and even less, to a maximum of 11, and the volatiles from 24 to 27 per cent. The present-day output is consumed mainly by power stations and in the domestic market.

There are two working coal fields in the area, namely, the Cornelia-Clydesdale fields immediately south of Vereeniging, and the Vierfontein fields south-east of Klerksdorp. The total proved and unproved coal in the former area is estimated at 11,000 million tons with an evaporative power of from 8 to 11, and the reserves of the latter area are estimated at 729 million tons with an evaporative power ranging from 9 to 10½.

CAPE PROVINCE

The coal fields of the Cape Province are contained in the Molteno beds which form the lower portion of the Stormberg series, that is the uppermost division of the Karroo system. In this region the Stormberg series occurs over a very considerable area estimated at close on 8,000 square miles. The coal measures occur on two distinct horizons, namely, the upper coal horizon containing the Molteno and Cyfergat seams, which is separated from the lower coal horizon by the Indwe sandstones. In the upper coal horizon the outcrops of the Molteno and Cyfergat seams have been recorded at a great number of points, but they are usually so thin as to be commercially valueless. In the Molteno district efforts have been made to work these seams from time to time without great success.

In the lower or Indwe coal horizon the principal development is in the neighbourhood of the town itself, where in places the seam attains a thickness of 14 feet of mixed coal and shale. It was in this area that the Indwe Railway and Collieries Company operated, the coal being used principally by the railways and Kimberley diamond mines. During the five years ended 1904, the annual output was at the rate of 108,000 to 132,000 tons, but thereafter it rapidly declined and at present does not exceed 2,000 tons per annum.

The quality of the coal in the Cape fields is very inferior, with high ash content, and rather low volatiles.

The coal is of such poor quality that no attempt has been made to estimate the tonnage available.

The total production of coal in the Cape Province for the year 1928 was 5,059 tons valued at £3,333 which is equivalent to 13s. 2d. per ton at the pit's mouth.

QUALITY OF COALS

The coals of South Africa are graded according to "calorific value" and "volatile contents." The usual unit of calorific value is the British thermal unit, but in South African practice it is the evaporative capacity of the coal that is generally referred to; that is to say the number of pounds of water that can be turned into steam by a pound of coal. The calorific value of a coal that will evaporate 13 lb. of water is stated as 13·00 lb. per lb. or simply 13.

The standard of good quality depends on the particular coal field from which the coal is derived. In Natal good quality coal has a calorific value of about 14·25, while in the Transvaal the equivalent grade is about 13·00.

The volatile contents of marketable coals produced in Natal are usually in the region of 18 to 20 per cent. although in one or two instances coals of 28 to 30 per cent. of volatile contents are being mined. In the Transvaal coals, the volatile contents are on the whole higher than in Natal coals, and average about 28 per cent. from the Witbank coal field.

Natal coals may be classed in most cases as semi-bituminous, whereas Transvaal coal invariably fall in the bituminous class. The sulphur content in good Transvaal coals is usually less than one per cent., whereas in Natal double this amount is not uncommon.

Typical analyses of good steam coal produced in the Witbank district of the Transvaal and from the Klip River and Vryheid districts of Natal are given below; and with them is that of a low-grade coal from Springs.

	Witbank.	Klip River.	Vryheid.	Springs.
Moisture	1·84	1·10	1·25	1·50
Ash	11·44	8·00	10·00	18·00
Volatile Matter ...	27·36	21·50	19·50	25·00
Fixed Carbon ...	59·36	69·40	69·25	55·50
Total	100·00	100·00	100·00	100·00
Sulphur	0·60	1·50	0·80	1·25
Calorific Value ...	13·25	14·50	14·25	11·00

In the Transvaal and Orange Free State several collieries are now producing a large tonnage of low-grade bituminous coal, the greater proportion of which is crushed to below $1\frac{1}{2}$ inch mesh and used in the power stations of the Victoria Falls and Transvaal Power Company Ltd., on the Witwatersrand and at Vereeniging.

Apart from this, these low-grade coals, by reason of their good geographical position, command a considerable market for domestic and certain industrial purposes, on the Witwatersrand, in the Orange Free State and in the northern parts of the Cape Province.

A typical analysis of this class of coal produced in the Springs area on the east Rand, is given in the table above.

In addition to the bituminous and semi-bituminous coals the Natal coal fields contain appreciable reserves of anthracites and semi-anthracites, ranging in volatile contents from 5 to 15 per cent. The market for this class of coal is very limited and does not exceed about 20,000 tons per annum. It is mostly used for the operation of suction gas plants.

COKING COAL

Coking coals are found mainly in the Klip River and Vryheid districts of Natal where several companies have erected plants for the manufacture of coke. Transvaal seams do not contain true coking coals though good coke has been produced from selected portions of the seams. In the Klip River coal field only certain well defined zones of the coal measures contain coking coal. Outside of these the coal is definitely of non-coking character. In the Vryheid district three of the four workable seams yield coal capable of producing good metallurgical coke. In every instance the coal must be carefully washed in order to reduce the ash and sulphur contents, for it has been found desirable to limit the ash content in the coke produced to about 12.50 per cent. Natal coke is of excellent quality for foundry work being very dense and hard. (See also under "The Manufacture of By-products.")

METHODS OF MINING.

Because of the small proportion of coal in the Transvaal and other South African deposits that is of the standard required by the mines, railways or shipping, a very large proportion of low-grade coal is left behind in mining. This is eventually lost because of fire or the collapse of the workings.

In both the Transvaal and Natal the coal seams are worked through adits or, either incline or vertical shafts, depending on the depth at which the seams are situated from the surface, and whether convenient outcrops are available in the locality. (Plate XXVIII.)

In the Witbank coalfield of the Transvaal, the vertical depth to the lower working seam varies from 50 feet to about 300 feet, and out of thirteen collieries now producing, only two are worked by vertical shafts.

In most cases the coal is hauled by the endless rope system direct to the surface in mine tubs through inclines over easy gradients. In three cases coal is hoisted by means of conveyer belts operating in inclines with gradients about 18° from the horizontal. The "bord and pillar" system of working has been adopted throughout the whole district, the size of pillars varying with the depth from the surface. As a general rule the pillars do not exceed 25 feet square with bords 20 feet in width. In several instances the "double stall" system has been tried with success.

The extraction obtained during primary development varies from 70 to 80 per cent., but it has been proved in several cases that even with the great thickness of seam, the secondary extraction or slicing of pillars will usually permit of from 85 to 90 per cent. extraction.

The workings of the Witbank district collieries are on the whole fairly dry, and the seams lie practically level which facilitates haulage conditions.

The size of mine tub used varies from a carrying capacity of 1,200 lb. to 2,000 lb., and probably averages about 1,400 lb. Steel tubs are used almost throughout the field. Track gauges underground are 18", 24" and in one instance 30". Haulages are operated on the endless over-rope system using positive clips.

Coal cutting is done by electricity and compressed air, but air machines are rapidly being eliminated in favour of electric cutters. Electric cutting was first developed in this field by Shortwall machines but these are gradually being replaced by the Arewall type. The British made coal cutter predominates in this district.

The average daily task of one coal cutter during an eight-hour shift is ten to twelve bords 20 feet in width, although this can be greatly exceeded during times of pressure.

Practically the whole of the Witbank mines are electrified, the current used being 3-phase 525 volts. A number of the collieries are now taking power from the super power station situated close to the town of Witbank, and controlled by the Electricity Supply Commission. The Commission's lines practically cover the whole of the coal field and power is available for any colliery at moderate

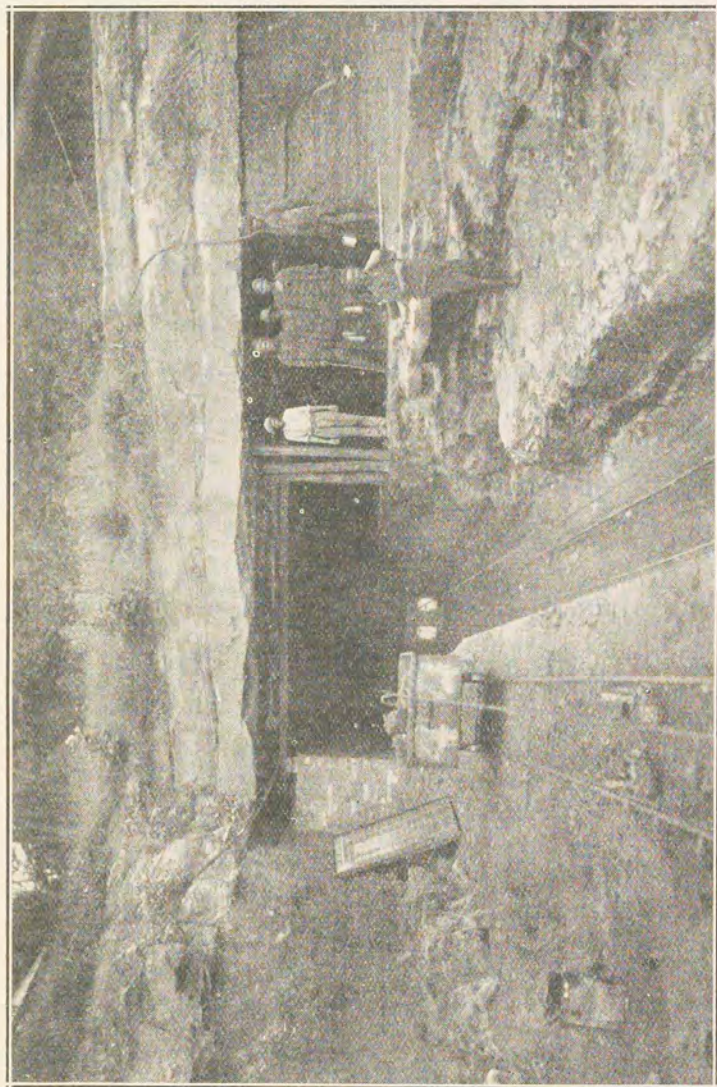


Plate XXVIII.—Hobaue Collieries, Natal. Native on right covers width of the coal seam.
[Photo, Publicity Dept., S.A. Railways.]



rates. The transmission pressure on the local lines owned by the Commission is 22,000 volts, this being reduced at the colliery sub-stations to 2,200. The tariff charged by the Commission is as follows:—

100s. per annum per k.v.a. maximum demand,
plus 0.06d. per unit,
plus an annual charge of £25.

In cases where the Commission has had to put in special lines, the collieries pay an annual amortisation charge on the capital expenditure involved in the installation.

It is possible for a colliery producing 50/60,000 tons per month to obtain its entire power requirements from the Commission for a sum varying between £200 and £400 per month dependent on the load and power factor.

The collieries of the Witbank district can be considered as fairly up to date, and the efficiency, by reason of the favourable mining conditions, is usually very good.

On a mine producing 2,000 tons per day—equal to about 50,000 tons per month—and purchasing its power requirements from the Supply Commission, the labour force would not exceed 900 natives and 40 Europeans.

The working conditions underground are excellent. There is plenty of height, good ventilation and the atmosphere is cool.

In the Natal coal fields, mining conditions are somewhat different to those obtaining in the Transvaal. The seams are thinner, the working depths are usually greater, and consequently different methods must be adopted.

The usual system is "bord and pillar," with bords 20 feet wide and pillars ranging from 40 feet square to 80 feet square, dependent upon the depths from the surface. The bord and pillar workings are usually laid off on the panel system to facilitate ventilation, the subsequent total extraction of the pillars, and to provide control over "gob" fires which may ultimately break out. On several collieries the longwall method has been employed with a fair amount of success, and so has the Welsh system or double stall method.

The collieries in Natal are on the whole dry and dusty, and in several cases, very fiery. Fire-damp and coal-dust explosions have already taken place on several collieries, with an unfortunately severe loss of life in one or two instances. In certain portions of the Natal fields, the coal is very susceptible to spontaneous ignition, and "gob" fires are a continual source of worry.

In the Klip River coal field, most the collieries are operated through vertical shafts.

In the Vryheid district, the mining conditions are somewhat easier than in the Klip River field due to the fact that adit mining is possible and fire-damp is only encountered on rare occasions.

In certain collieries in the Vryheid district, three contiguous seams are being worked simultaneously, care being taken to arrange that the pillars are superimposed. Coal cutting is done in most cases by electric machines, although on the more fiery mines, compressed air is still being extensively used. Both the Shortwall and the Arewall type of electric machines are in use.

Natal coals are very soft and friable as compared with Transvaal coals, and a single Shortwall coal cutter will cut as many as 25 bords each 20 feet in width, during a shift of eight or nine hours.

Underground transport is done almost entirely by endless rope haulages operating on the over-rope system. The size of the mine tub varies from 1,000 lb. to 1,500 lb. capacity. The track gauge is invariably 24 inches wide.

The collieries in Natal generate their own supplies of electric power and compressed air.

METHODS OF SCREENING, SORTING AND WASHING.

Throughout the collieries of the Union, marketable coal is classified into the following sizes:—

Rounds: Plus $1\frac{1}{4}$ " or where cobbles are extracted, plus $3\frac{1}{2}$ ".

Cobbles: Plus $1\frac{1}{4}$ " or $1\frac{1}{2}$ " minus $3\frac{1}{2}$ ".

Nuts: Plus $\frac{3}{4}$ ", minus $1\frac{1}{4}$ " or $1\frac{1}{2}$ ".

Peas: Plus $\frac{3}{8}$ ", minus $\frac{3}{4}$ ".

Duff: Minus $\frac{3}{8}$ ".

(These sizes refer to round holes.)

The methods of screening adopted are very similar throughout the whole country, excepting that in Natal the small coal is usually washed.

In the instance of a colliery where the tubs are brought into the screening plant, the screening operation is carried out in the following typical manner.

The mine tubs containing run-of-mine coal are placed in revolving tipplers, from where the coal is delivered on to either jiggers containing perforations, or revolving grizzlies, where in both cases the small coal either from

nut size down or from cobble size down, is screened out. The over-size, which is round coal, is delivered from the jiggers on to picking or sorting belts, these being usually made of steel plates from 50 to 75 feet in length, and from 4 to 6 feet in width. In one or two cases, rubber picking belts similar to those on the gold mines are now being used. The coal is distributed as uniformly as possible over the picking belts, which travel at a speed of 50 to 70 feet per minute through the sorting house, and the foreign matter is hand-picked by natives. At the end of the picking belt the round coal is usually delivered direct into railway trucks. The small coal which is screened by the jiggers or the grizzlies is collected underneath on a conveyor belt or other conveying apparatus, which takes it to the small coal screening plant. The small coal screening plant is usually equipped with either revolving trommels or vibrating screens, which classify the smalls into three sizes, namely, nuts, peas and duff.

In the Transvaal collieries it is customary to equip the small coal plant with a storage bunker, divided off to hold several hundred tons of each class of coal, this being a precautionary measure against loss of time arising from truck shortage. On several collieries, provision is also made for storing round coal in a bunker situated adjacent to the screening plant. The capacity of these bunkers ranges from 1,000 to 1,500 tons. At one colliery provision has been made for storing up to 10,000 tons of run-of-mine coal on the ground adjacent to the screening plant, suitable equipment being provided to load up this coal quickly and pass it through the screening plant for classification.

On collieries where cobble coal is made, suitable screening jiggers or grizzlies are installed, usually in the round coal plant to classify out the product ranging from plus $1\frac{1}{4}$ " to minus $3\frac{1}{2}$ ".

On the Transvaal collieries only dry classification takes place. The washing of small coal was carried out for some years at one of the collieries, but it was finally abandoned.

On the whole the screening plants in the Transvaal collieries are of fairly modern design, and in several instances capacities of 3,000 to 4,000 tons output per day have been provided for.

In the Natal coal fields the screening methods are somewhat similar to those adopted in the Transvaal, but at the great majority of mines coal washing plants have been installed for treating small coal.

Washing as a rule is confined to nuts and peas, but in one or two cases duff coal is also washed where this is required for coking purposes.

At one colliery spiral separators have been installed for cleaning cobbles and nuts. The following types of coal washers are in use in these fields, namely:—The “ Baum ” washer, the “ Coppee ” Baum washer, the “ Nota-Nos ” washer and the “ Draper ” washer. There are two installations of the Draper type of washer, these being used exclusively for washing fine coal required in connection with the manufacture of coke. The quality of Natal nuts and peas after washing, is as a general rule fairly high. These productions command an excellent sale throughout the country on account of their purity and high calorific value, as compared with small coal produced in the Transvaal.

From certain collieries, an excellent class of smithy nuts and peas is produced, and sold throughout the whole of the Union.

The practice of storing round coal in bunkers, is carried out extensively in Natal where the shipping trade often requires that large tonnages be despatched at short notice.

THE MANUFACTURE OF BY-PRODUCTS.

During the year 1928, 247,699 tons of coal were converted into by-products as follows:—

Coke: 103,716 tons produced in Natal.

Tar: 209,922 gallons produced in the Transvaal and 319,976 gallons produced in Natal.

Ammonium Sulphate: 1,055 tons produced in Natal.

Coke

Coke is at present produced at six collieries in Natal, two in Klip River and four in the Vryheid coal fields. In Natal all coke is produced from dross coal after washing. At the Waschbank Coke and By-products Works in the Klip River country there are fifty retort ovens capable of producing about 5,500 tons of saleable coke per month, as well as tar, creosote, naphthaline, benzol and ammonium sulphate. In the Vryheid coal fields there are about 200 beehive and barrel type ovens with a producing capacity of 6,000 tons of saleable coke per month.

The specifications called for in certain local contracts for metallurgical coke are as follows:—

Fixed carbon to be not less than 84 per cent., ash not over 13·5 per cent., sulphur not over 1·00 per cent. The average analyses of Natal coke are as follows:—

COAL AND OTHER FUELS

	Waschbank. Per cent.	Vryheid. Per cent.
Fixed carbon	86.24	86.32
Ash	11.35	12.25
Sulphur	1.01	0.75
Moisture	1.40	0.68
	<u>100.00</u>	<u>100.00</u>

The Transvaal seams do not contain true coking coals, although in several instances good coke has been produced from selected portions of the beds and it has recently been established that mixtures of Natal and Witbank coal will produce good metallurgical coke. The availability of coking coal and the economics of coke production from Transvaal coals, is a subject now being investigated very closely by the Transvaal Coal Owners Association.

The present capacity for coke production in the Union is about 138,000 tons and the production in 1928 was 103,716 tons, all of which came from Natal. The reserves of true coking coal in South Africa are in the present state of our knowledge, confined to Natal, where it is estimated that about 600 million tons are probably available. This tonnage must not be taken as any criterion of the coking coal reserves of the Union, for apart altogether from the possibilities of producing metallurgical coke from selected Transvaal coals, the fact that blending has been proved to yield satisfactory results, greatly increases the reserves of coal falling within the category of coking coals.

There is only one by-product coking plant at work in South Africa, namely, at the Waschbank works of the Dundee Coal Company in Natal. The South African Carbide and By-product Co., Ltd., situated at Ballengeich in Natal are producing carbide, but the low temperature carbonization plant has been closed down.

The following table indicates the value of output of coal by-products in recent years:—

Year.	TRANSSVAAL.				NATAL.				
	Coke.	Tar.	Sulph. Ammon.	Other Products.	Coke.	Tar.	Sulph. Ammon.	Other Products.	Total.
	£	£	£	£	£	£	£	£	£
1918 ...					68,662		86,299		154,961
1919 ...		135			47,312		102,930		150,377
1920 ...	81	3,382			48,454		63,088		115,005
1921 ...	437	5,104		528	50,723		19,470		76,282
1922 ...		46	132	71	57,758	3,575	2,914		64,496
1923 ...		27			76,294	8,570	7,531	1,276	93,698
1924 ...				38	90,537	9,180	12,987	1,802	114,544
1925 ...		1,250		602	92,643	7,191	11,920	3,408	117,014
1926 ...		6,839		694	106,153	8,627	10,680	4,350	137,343
1927 ...	40	10,064		734	120,469	9,034	10,335	7,553	158,229
1928 ...		11,099		733	97,937	13,159	11,064	9,071	143,063

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

The outlook for by-products at the present time is not satisfactory, owing to the restricted nature of the local market. Some efforts have been made to create an export market for coke, but with only moderate success.

South African coals, especially those in Natal, are not particularly rich in volatile hydrocarbons, and the theoretical extraction of tar, ammoniacal liquors and spirits is in many cases very low.

An unsuccessful attempt was made about fifteen years ago by the Mond Group to establish works for the manufacture of ammonium sulphate from anthracites, rich in nitrogen, but after operating for a few years, the fall in the price of sulphate compelled these works to close down and they have now been demolished.

The possibilities of establishing a plant in this country for the hydrogenation of coals and the production of motor spirit are now being considered.

GOVERNMENT REGULATIONS

As in the case of metalliferous mines, the Government exercises a certain amount of control over the mining of coal. (See Chapter X.) Responsibility for the carrying out of the Mines and Works Act is apportioned by law amongst the various officials in a mine, each of whom is required to pass an examination to prove that he is competent to perform the duties required of him. Government inspectors pay frequent visits to the mines to see that regulations bearing on matters of safety are complied with.

GRADING REGULATIONS

The Coal Grading Act of 1922 came into effect on September 1, 1922, the main provisions of which may be summarized as follows:—

1. No coal produced within the Union is to be used for export or bunkering unless it has been graded and a certificate in the prescribed form has been granted in respect thereof.
2. A committee to control the grading of coal may be appointed, consisting of a chairman, nominated by the Minister, and four members, either all nominated by the collieries, or two nominated by the collieries and two by the Minister. Members and officers of the grading committee may enter any colliery or place where there is coal at any time. Reasonable assistance in the work of grading and inspecting must be given by the officers and servants of the colliery or place concerned with the bunkering and export of coal.
3. A monetary levy is to be made on the collieries by the grading committee at the commencement of its operations, this levy to be based upon the tonnage shipped by the several collieries during the preceding six months. Every quarter afterwards

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the amount levied is fixed in proportion to the amount of coal supplied during the preceding quarter by each of them for export and bunkering.

4. Export and bunkering of coal may be restricted or prohibited by the Minister if there is any real or apprehended scarcity.

Coal Grading Committees each consisting of a chairman and four members are appointed by the Minister for Natal and the Transvaal. The collieries wishing to export coal in these two provinces of the Union, were sampled and the calorific value of the product was in each case determined. Standards were fixed, the following being adopted:—

NATAL

First Grade, 13·5 with a permitted variation of 2·00 per cent., thus making the lowest first grade to pass a standard of 13·25 calorific value.

All below this was graded second class.

If the ash of any coal fused below 1,300° C., a note to this effect was inserted in the grading certificate.

TRANSVAAL

Witbank: A. 12·75 or above

Witbank: B. Below 12·75 but 12·25 or over.

Ermelo: A. 12·00 or above.

Ermelo: B. Below 12·00 but 11·5 or over.

These regulations have had the effect of standardizing the quality of coal exported from the Union and greatly reduce the harmful effects which often arise from consignments of bad coal being exported to other countries.

In addition to the standards called for by the Coal Grading Act, the gold mines of the Rand call for a certain standard of value, the present guarantee given by the Transvaal Coal Owners' Association being a calorific value of 12·80, which is the same as for export coal.

The quality of coal supplied to the Railway Administration while not usually subject to a calorific guarantee is frequently tested on certain defined railway routes for burning efficiency.

Municipalities and certain other industries buy most of their coal supplies on a calorific basis. This will be readily understood when it is appreciated that in the case of small coal such as peas, supplied from a colliery in the Transvaal to a consumer in Cape Town, the delivered price of the coal may be 25s., of which only 3s. 6d. represents the pit's mouth price, the consumer paying as much as 21s. 6d. per ton railage.

MARKETING AND DISTRIBUTION

The coal output of the Union is marketed and distributed entirely by private enterprise.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

In the Transvaal a large number of the collieries have formed themselves into a body called the "Transvaal Coal Owners' Association" which performs the functions of a selling organization. At the present time there are eighteen associated collieries in this organization, of which 11 are situated in the Witbank area, 2 in the Ermelo-Breyten area, 2 in the Springs district, 2 in the northern Free State (close to Vereeniging) and 1 in the southern Rand area.

The total output sold by the Transvaal Coal Owners' Association for the year ended June 30, 1929, amounted to 6,767,535½ tons. The Association handles from 75 to 80 per cent. of the total Transvaal output.

The associated collieries participate in the total trade of the Association on an allotment basis, the allotments being fixed for a period of five years by agreement.

The Transvaal Coal Owners' Association has been operating since the year 1910, prior to which each colliery company disposed of its own output to the best advantage. The Association is re-formed every five years, when a revision in allotments usually takes place.

The advantages of this huge selling organization have been amply demonstrated during the past twenty years, to the complete satisfaction of both producer and consumer.

The Transvaal Coal Owners' Association does not act as retailer in the case of small consumers such as householders, these being catered for by private retailers who obtain supplies under agreement with the Association.

The largest individual consumer of Transvaal coal is the South African Railways, which takes from 30 to 35 per cent. of the total output. Next comes the Victoria Falls and Transvaal Power Co., Ltd., which, together with the Electricity Supply Commission, consumes about one and three-quarter million tons per annum in the large power stations situated at Witbank, on the Rand and at Vereeniging. A great proportion of the coal consumed by the power stations is low priced "smalls" such as duff and peas. The mines come third on the list in point of tonnage consumed although as a source of revenue to the collieries, they are next to the railways in importance.

The proportion of the total output shipped to Lourenço Marques is at present very small, being in the order of 5 or 6 per cent., and to Cape Town about 1½ per cent. The balance of the output is taken by local industries, municipalities and domestic consumers situated in the Transvaal, Orange Free State and the Cape Province.

COAL AND OTHER FUELS

In the Natal coal fields there is no selling organisation such as that just described in the Transvaal, each colliery disposing of its output to the best advantage in competition with the others.

Approximately one-half of the Natal output goes to the shipping trade at Durban, Port Elizabeth and Cape Town. The balance is taken by the railways, municipalities, industries and domestic consumers.

The following table shows the quantity of coal (tons of 2,000 lb.) from mines in the Union bunkered and exported during the year 1928:—

Port.	Tons of Coal Bunkered.	Tons of Coal Exported.
Capetown	263,232	192
Durban	1,085,288	1,378,922
Other Union Ports	14,449	376
Lourenço Marques ..	289,736	268,659
Total	<u>1,652,705</u>	<u>1,648,149</u>

The proportion of the Union's coal output used for bunker and export purposes during 1928 amounted to 24·6 per cent.

The following table shows the quantity of coal imported into, exported from, and consumed in, the Union during the years 1911-1928:—

Year.	Consumption of Coal in the Union.			Coal Imported.	Coal Exported.	Coal Bunkered‡
	Total.	Railway†	Mines.			
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1911	6,139,481	1,463,226	2,608,643	68,035	82,586	1,440,912
1912	6,598,981	1,671,528	2,472,308	75,116	166,983	1,426,230
1913	6,546,601	1,895,349	2,535,451	57,709	856,397	1,455,927
1914	6,544,181	1,928,828	2,108,397	77,266	651,211	1,359,797
1915	6,497,716	1,875,377	2,241,131	28,495	506,551	1,305,552
1916	7,291,080	2,304,966	2,507,389	13,689	565,663	2,164,448
1917	7,510,366	2,381,554	2,537,022	15,003	539,473	2,348,084
1918	7,386,546	2,271,970	2,471,222	10,070	1,210,697	1,290,152
1919	7,748,958	2,470,104	2,516,104	10,158	1,093,842	1,433,493
1920	8,322,218	2,745,681	2,338,849	7,741	1,301,272	1,857,715
1921	7,974,993	2,432,427	2,098,500	16,085	1,795,093	1,642,004
1922	6,833,954	2,258,409	1,672,088	13,592	1,477,657	1,436,294
1923	8,208,971	2,644,544	2,149,986	11,627	1,903,717	1,815,975
1924	8,759,150	2,789,944	2,206,406	12,919	1,925,038	1,820,636
1925	9,287,557	3,107,081	1,739,878	18,275	1,759,626	1,970,758
1926	9,439,471	3,125,982	2,163,797	23,172	2,354,468	1,963,696
1927	9,664,629	3,170,456	2,128,100	6,374	1,804,694	1,839,831
1928	10,109,528	3,263,973	2,113,443	6,967	1,648,149	1,652,705

† Steam coal only.

‡ Shipped in vessels cleared overseas only.

RAILWAY RATES AND PRICES

The railway rates on coal throughout the Union are controlled by a special tariff, which operates equally in the

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

four provinces. The tariff is designed to give some relief to the consumer situated at great distances from the pit's mouth.

Special rates are also fixed for export and bunkers, in such a fashion that the collieries most favourably situated from a geographical point of view, do not possess too great an advantage over those otherwise situated.

The following shows the railage rate per ton of coal (2,000 lb.) used for internal purposes over various distances :

Mileage.	Rate per ton excluding cross-over charges which vary from 1d. to 4d. per ton.		
1 to 4	...	...	1s. 3d.
5	...	...	1s. 5d.
6	...	...	1s. 7d.
8	...	...	1s. 11d.
10	...	...	2s. 3d.
20	...	...	3s. 3d.
40	...	...	4s. 8d.
60	...	...	5s. 11d.
80	...	...	6s. 9d.
100	...	...	7s. 4d.
200	...	...	9s. 10d.
500	...	...	15s. 3d.
750	...	...	18s. 5d.
1,000	...	...	21s. 4d.

The railage rate—excluding cross-over charges—on shipment coal from the various coal-fields to the principal ports, is as follows:—

Witbank Coal Field.	Miles.	Export Coal per ton.	Bunker Coal per ton.	Carrying Bunkers per ton.
		s. d.	s. d.	s. d.
To Lourenço Marques ...	276	5 3	12 6	5 3
East London ...	736	14 5	16 0	14 5
Port Elizabeth ...	784	14 5	16 0	14 5
Cape Town ...	1,045	14 5	16 0	14 5
Natal Coal Field. (Average of Klip River and Vryheid)	Miles.	Export Coal per ton.	Bunker Coal per ton.	Carrying Bunkers per ton.
		s. d.	s. d.	s. d.
To Durban ...	275	5 4	12 7	5 4
East London ...		14 5	16 0	14 5
Port Elizabeth ...		14 5	16 0	14 5
Cape Town ...	1,133	14 5	16 0	14 5

The railage rate on coal consumed by the gold mining industry *ex* the Witbank coal field averages about 7s. 3d. per ton.

The railage rate on coke is the same as for coal.

COAL AND OTHER FUELS

PRICES

The prices paid at the pit's mouth for various classes of coal—per ton of 2,000 lb.—are as follows:—

	Transvaal.		Natal.	
Round Coal—	s. d.	s. d.	s. d.	s. d.
Railways	5 0	to 5 9	4 6	to 5 6
Shipment Export ...			4 0	to 5 0
Shipment Bunker ...			7 0	to 8 6
Industries	6 0	to 7 0	6 0	to 7 0
Mines	6 6			
Domestic	6 0	to 7 0	6 0	to 7 0
Export	4 0	to 5 0		

Cobbles—

Similar to Round Coal prices.

Nuts—

All purposes	4 0	to 4 9		
Ordinary (washed) ...			5 0	to 6 0
Smithy (washed) ...			6 0	to 9 0

Peas—

Ordinary (washed) ...	3 0	to 4 0	3 6	to 6 0
Smithy (washed) ...			6 0	to 8 0

Duff	1 0	to 2 6	1 0	to 1 6
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The following table shows the average prices of coal (pit's mouth) in the Union for the period 1911-1928:—

Period.		Cape Good Hope.	Natal.	Transvaal.	Orange Free State.
		Per Ton.	Per Ton.	Per Ton.	Per Ton.
1911	...	11s. 6-98d.	5s. 4-98d.	4s. 8-39d.	5s. 8-42d.
1912	...	11s. 0-55d.	5s. 6-99d.	4s. 4-78d.	5s. 4-57d.
1913	...	11s. 5-82d.	6s. 1-83d.	4s. 4-48d.	5s. 5-87d.
1914	...	11s. 7-50d.	6s. 10-80d.	4s. 5-55d.	5s. 5-58d.
1915	...	11s. 4-22d.	6s. 9-50d.	4s. 4-82d.	5s. 2-14d.
1916	...	11s. 6-49d.	7s. 4-77d.	4s. 6-07d.	5s. 2-54d.
1917	...	14s. 4-05d.	10s. 1-76d.	4s. 9-32d.	5s. 1-86d.
1918	...	15s. 3-89d.	10s. 5-10d.	5s. 0-84d.	5s. 6-70d.
1919	...	15s. 9-12d.	10s. 7-41d.	5s. 1-40d.	5s. 6-25d.
1920	...	15s. 5-22d.	12s. 3-40d.	6s. 1-12d.	5s. 11-43d.
1921	...	15s. 7-91d.	14s. 1-71d.	6s. 7-32d.	6s. 0-82d.
1922	...	15s. 2-86d.	9s. 2-80d.	5s. 7-34d.	5s. 9-12d.
1923	...	14s. 5-76d.	7s. 10-70d.	5s. 3-04d.	5s. 6-61d.
1924	...	14s. 2-37d.	7s. 8-89d.	5s. 0-90d.	5s. 6-79d.
1925	...	14s. 4-98d.	7s. 5-13d.	5s. 0-67d.	5s. 6-88d.
1926	...	13s. 11-63d.	7s. 2-99d.	5s. 0-00d.	5s. 7-46d.
1927	...	13s. 4-63d.	6s. 10-83d.	5s. 0-30d.	5s. 6-29d.
1928	...	13s. 2-12d.	6s. 3-88d.	4s. 11-63d.	5s. 5-45d.

PRODUCTION

The tonnage and value of coal produced in the Union from the earliest date for which complete records are available are given in the following table:—

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA
ANNUAL OUTPUT OF COAL, VALUE, AND VALUE PER TON, FROM 1885.

Year.	Quantity.				Value.		Average Value per Ton.
	Cape.	Natal.	Transvaal.	Orange Free State.	Union.	Union.	Union.
	Tons.	Tons.	Tons.	Tons.	Tons.	£	s. d.
1885-89*	23,314	28,682§	—	No records available.	Records incomplete.	Records incomplete.	Records incomplete.
1890-94*	46,219	130,461	669,946†	records available.	incomplete.	incomplete.	incomplete.
1895-99*	143,986	299,417	1,562,813	417,897	5,204,539	1,967,480	6 5
1900-01*	193,993	666,444	1,511,252	129,911‡	3,673,023‡	1,561,139‡	8 6‡
1905-06*	135,435	1,647,412	3,003,795	557,420	8,020,694	2,060,221	5 2
1910-14*	76,576	2,696,256	4,690,442	727,553	8,281,324	2,142,479	5 2
1915	46,850	2,304,116	5,202,805	782,576	10,007,502	2,739,665	5 6
1916	41,752	3,066,261	6,136,913	843,095	10,382,920	3,275,608	6 4
1917	8,300	2,890,296	6,641,229	826,577	9,877,325	3,224,597	6 6
1918	4,654	2,607,133	6,438,961	838,059	10,266,135	3,416,244	6 8
1919	4,759	2,801,004	6,622,313	966,034	11,473,464	4,519,665	7 11
1920	5,700	3,321,606	7,180,124	917,776	11,396,905	5,072,401	8 11
1921	5,778	3,525,989	6,947,362	729,113	9,734,313	3,395,176	7 0
1922	6,813	3,618,093	5,380,294	865,496	11,917,036	3,713,706	6 3
1923	6,359	4,302,892	6,742,289	982,596	12,491,905	3,824,746	6 1
1924	5,329	4,713,291	6,790,689	974,324	12,999,666	3,862,118	5 11
1925	5,608	4,622,339	7,397,395	976,245	13,734,463	4,046,620	5 10
1926	5,201	5,159,549	7,533,468	1,039,905	13,302,780	3,825,664	5 9
1927	4,430	4,852,826	7,405,619	1,088,109	13,403,415	3,672,966	5 6
1928	5,059	4,641,145	7,609,102				

* Average. § For year 1889 only. † Average for years 1893 and 1894.
‡ For year 1904 only.

AVAILABLE RESERVES

The available reserves of coal in the Union of South Africa have within recent years been the subject of very close investigation by the Department of Mines and Industries, and the results are embodied in three official memoirs under the authorship of W. J. Wybergh.

While a large number of known coal-bearing areas still remain unprospected, the broad position in regard to the extent and contents of the various coal fields is now known with greater accuracy than hitherto.

The estimated total coal resources of the Union are on the order of 225 thousand million tons. A very great proportion of this tonnage is in respect of coal which, according to present-day standards, is of inferior quality. On the other hand an abundance of good quality coal has already been proved and this is sufficient to serve the needs of the country for several hundreds of years even after allowing for a considerable increase on the present rate of consumption.

The position in regard to available reserves in the Natal fields is not perhaps as satisfactory as elsewhere, but several large areas still remain to be prospected in this field. It is probable that within the next hundred years,

many of the Natal areas containing second grade coal, may have to be opened up, when the standard of quality will be adjusted to a lower basis, similar to that of the Transvaal.

Although the Union is wonderfully endowed with large coal fields, it is unfortunate that so much of its reserves are of poor grade. There is an especial lack of good coking coals, which in the present state of our knowledge, are confined to Natal, and are, unfortunately, now being largely mined to satisfy the requirements of the steam coal market.

A shortage of this class of coal will undoubtedly be felt sooner or later, unless by that time some simple and cheap commercial process is evolved whereby non-coking coals may be changed into coking coals.

With regard to the huge areas of low-grade coal with which this country abounds, it is quite possible that fuel research may in time point to a way whereby these coals may be beneficiated so as to improve their value for fuel purposes. Great strides have been made within recent times in the use of low-grade fuels, in South Africa, and there is no doubt that as time goes on, further progress will be made in this direction. Several of the large power stations have been consuming these low-grade coals for many years, with great success.

Bearing these facts in mind, it is within the bounds of possibility that the coal resources of the Union may possibly outlast the "coal age" that we now live in.

The following table gives the results of Wybergh's estimates. He has omitted an estimate of the coals occurring in Zululand, in which territory there are enormous quantities of low-grade coal.

COAL RESOURCES OF THE UNION OF SOUTH AFRICA.

(Extracted from Geological Survey Memoir No. 19 (W. J. Wybergh), Vols. I, II, and III.)

Coalfields.	Proved.		Estimated Tons of 2,000 lb.	Undetermined Tons of 2,000 lb.	Total Tons of 2,000 lb.
	Calorific Value over 12 Tons of 2,000 lb.	Calorific Value under 12 Tons of 2,000 lb.			
Transvaal—					
Witbank	759,588,000	2,235,807,000	2,738,173,000	1,500,000,000	7,238,548,000
Springs-Heidelberg	—	344,839,000	2,818,000,000	8,107,744,000	11,270,583,000
Eastern Witbank	—	596,249,000	3,799,890,000	1,500,000,000	6,457,804,000
Bethal	—	—	—	7,508,000,000	7,508,000,000
Ernest-Middelburg-Bellast	141,310,000	250,900,000	1,913,600,000	3,536,000,000	5,841,810,000
Piet Retief-Wakkerstroom	1,500,000,000	—	1,060,000,000	5,690,000,000	8,250,000,000
Springbok Flats	—	—	—	12,000,000,000	12,000,000,000
Waterberg	—	—	—	7,400,000,000	7,400,000,000
Zoutpansberg	—	—	No estimate possible	—	—
Sydenhamsburg No. 32	—	10,000,000	—	—	10,000,000
Komatipoort	—	—	No estimate possible	—	—
Natal—					
Klip River	433,290,000	19,912,000	777,345,000	918,500,000	2,149,047,000
Vryheid	260,341,000	16,761,000	294,398,000	—	571,500,000
Utrecht	41,456,000	52,642,000	1,132,794,000	4,880,000,000	6,106,892,000
Orange Free State	—	1,500,350,000	471,900,000	150,000,000,000	151,972,250,000
Cape Province	—	Not estimated because of poor quality.	—	—	—
Union of South Africa—Totals	3,697,630,000	5,027,493,000	15,006,100,000	293,040,244,000	226,771,431,000

† Of the "proved" coal in Natal 40 per cent. contains less than 16 per cent. volatiles. ‡ See succeeding page.

The following notes are explanatory of the foregoing table:—

The basis of this estimate is as follows:—

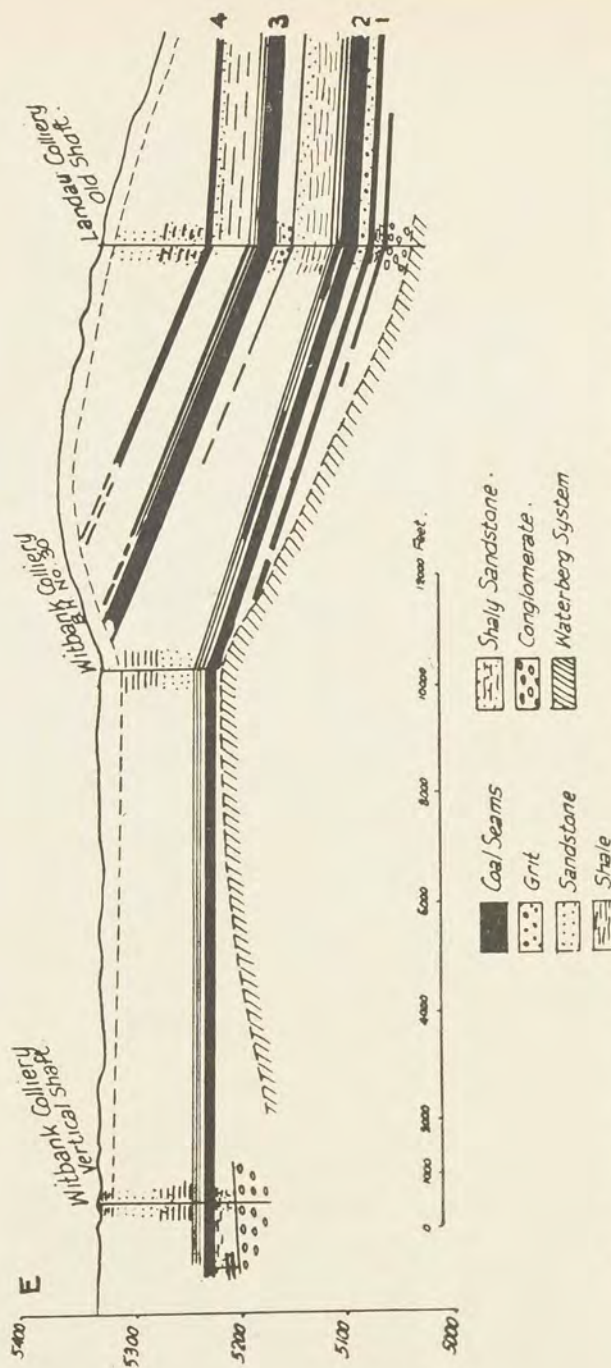
No seam is included which has a thickness less than 3 feet of clean coal, except to a very limited extent in Natal. There are, however, many such seams in most of the coal fields, which, in the aggregate, contain large amounts of coal.

“Proved” coal is, except in the case of the Piet Retief-Wakkerstroom field, taken to mean coal which has been sufficiently prospected to warrant immediate opening up, where the quality and economic conditions permit.

“Estimated” coal is taken to mean coal, the existence of which is fairly certain, but which requires further investigation to warrant the expenditure of capital.

“Undetermined” coal is that about which little is known in detail, but of the probable existence and extent of which there is good geological evidence sufficient to warrant prospecting.

Estimated and undetermined coal are not classified according to calorific value or volatile contents. Large quantities of low-grade coal, probably of calorific value less than 10, have, nevertheless, been entirely omitted from the estimate.



Section across the Witbank Coalfield (the geological formation between the exposures is conjectural.)

After P.A. Wagner.

FUTURE OF THE INDUSTRY

The development of the coal industry of the Union is one of very slow expansion. In the year 1915 the total output had reached just over 8 million tons. For the year 1928 the total was close on $13\frac{1}{2}$ million tons, showing an increase of $5\frac{1}{2}$ millions, equal to 69% for a period of 13 years. During the past ten years, the Union's greatest period of industrial expansion, the coal output has increased by only $3\frac{1}{2}$ million tons. Ten years ago, the shipment trade amounted to $2\frac{1}{2}$ million tons per annum; to-day it is at the rate of only $3\frac{1}{4}$ million tons per annum.

Owing to price competition from other countries, freights, and the great reduction which has recently taken place on inward cargo, the Union's shipping trade in coal does not show the expansion that was at one time anticipated. Export coal is to-day being sold at a level much below the ruling prices in the internal market, in an attempt to foster trade. Most of the present-day export business is showing a loss. The only advantage retained by the collieries is the higher price for bunkers. Should this disappear, the Natal coal trade would be badly affected.

Another factor which has given the Natal coal trade a set-back, is the transfer of a number of steamers operating between Australia and the United Kingdom to the Suez route, instead of via Cape Town.

The advent of oil-burning and oil-driven vessels has also, within recent times, given rise to further restrictions in the shipping business. In consequence of these and other factors the shipment tonnage of Transvaal coal through Lourenço Marques is only about half of what it was ten years ago.

The electrification of a large section of the Natal main line a few years ago, greatly reduced the revenue earning trade in round coal with the railways. To-day this busy section of the main line is being operated from the Colenso power station, which consumes something like 100,000 tons of small coal per annum, for which the collieries receive 1s. to 1s. 6d. per ton at the pit's mouth.

At the present time the future of the Union's coal trade would appear to be more in the development of its own internal market than in the shipping market. The completion of the iron and steel works at Pretoria under Government auspices will in due course stimulate the consumption of coal inland, and doubtless in time other subsidiary industries will start up with additional demands.

The possibilities of establishing plants in this country for the liquefaction of coal by hydrogenation, are at present being investigated by experts from overseas. The consumption of motor spirit in the interior regions of South Africa, is increasing at a very rapid rate, and all of it has to be conveyed in bulk over the railways at considerable cost to the consumer. The railage barrier between the coast and the interior is a factor which ought to weigh greatly in favour of any attempt to establish plants capable of producing motor spirit in the regions away from the coast.

The development of this industry would be welcomed by the collieries.

The possibilities of establishing further by-product coking plants, are at the moment not encouraging, and it is unlikely that further developments will take place in this direction for some time to come. It is understood that the coke requirements of the Government iron and steel industry at Pretoria will be provided for by the erection of a coking plant on the spot, operated and controlled as part of the Pretoria scheme. In this event the collieries will only be called upon to supply coking coal.

OTHER FUELS

In the following section lignite, natural gas, oil shale and petroleum are discussed.

LIGNITE

Beds of impure lignite occur in the Uitenhage beds, Neocomian, of the south coast region of the Cape Province. They are apparently of very limited extent and of no economic importance.

In the Knysna district beds of lignite up to 8 feet thick occur in some unconsolidated sandy deposits of probably Tertiary age. They were first opened up in 1908. Since then no further developments have taken place, and it is to be concluded therefore that they did not prove worthy of exploitation.

There is a deposit of lignite on the west coast of the Cape Province in the Van Rhynsdorp division about 20 miles north of the mouth of the Olifants River. And beds of lignite have been found also on the coast of Zululand.

As far as is known, none of the lignite deposits have been utilized up to the present time.

NATURAL GAS

Natural gas has been struck in considerable quantity on the farm Gruisfontein, in the Heidelberg district of the Transvaal, where it is encountered at a depth of 540 feet below a sill of dolerite that acted as an impervious cover. There may be other isolated reservoirs of gas in the area, and it is possible that the Fauresmith district of the Orange Free State and the Folded Belt along the southern margin of the Karroo offer favourable conditions for the occurrence of gas.

Large quantities of firedamp (methane) have issued for long periods from boreholes in the coal measures in Natal.

Large volumes of pure carbon dioxide issue along a fault in Dwyka tillite on the farms Huhenden, Lots 10 and 7 in Alfred County, Natal. The gas is collected and used for aerating mineral waters.

OIL SHALE

True torbanite, consisting largely of minute "kerogen" bodies is developed on several horizons in the coal measure series (middle Ecca) of the Karroo system, in the Bethal, Ermelo and Wakkerstroom districts of the Transvaal, and in the Utrecht and Dundee districts of Natal. The torbanite beds are generally found underlying or inter-bedded with thin seams of coal. They are unfortunately thin compared with beds of oil shale found in other parts of the world, their thickness ranging from 6 inches to 3 feet. The torbanite yields from 20 to 100 gallons of oil per ton, and from 8 to 48 lb. of ammonium sulphate.

The most promising deposits so far discovered are on the farms Mooifontein 287 situated in the Ermelo district, 8 miles north of Ermelo and on the farm Kromhoek 76, Virginia 371, Goedgevonden 77, and Yzermyn 280 in the Wakkerstroom district. Recently a seam of torbanite has been located near Greylingstad in the Heidelberg district of the Transvaal, on Herpsfontein 234 and adjoining farms. Efforts are at present being made to raise capital to provide plant for working these several deposits. A good deal of exploratory work has also been done on the carbonaceous oil-yielding shale occurring in the Stormberg series in the Impendhle district of Natal. This yields up to 32 gallons of oil per ton.

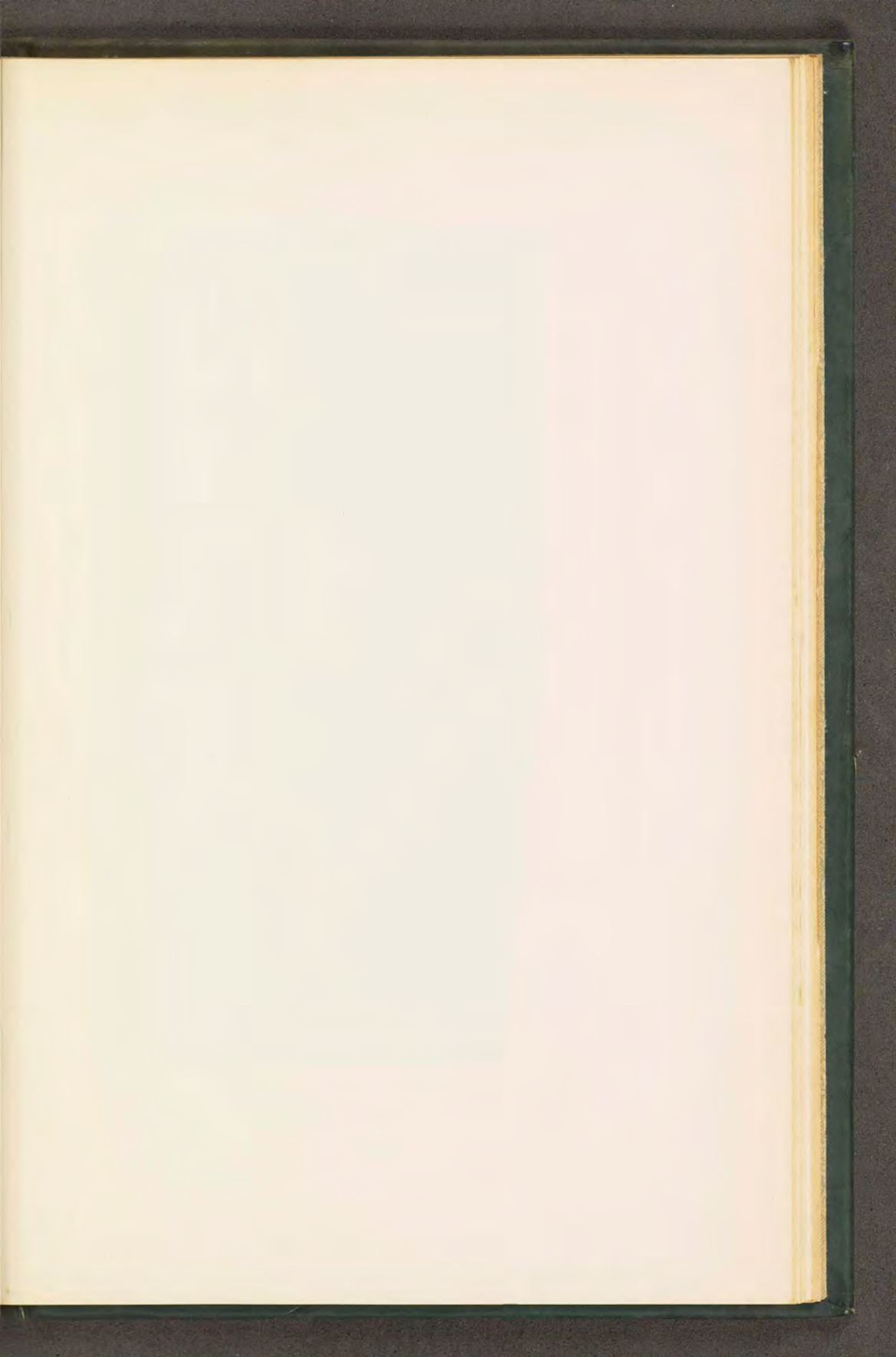
PETROLEUM

Seepages of petroleum occur at numerous localities in the area occupied by the rocks of the Karroo system, generally in or in the neighbourhood of intrusions of dolerite, and have led to a great deal of costly prospecting. There is one tract of country in the Union that offers some, at any rate, of the requisite conditions for the accumulation of oil in commercial quantities. This is the Folded Belt along the southern margin of the Karroo. The evidence of the existence or former existence of oil in this belt is furnished by peculiar veins of pseudo-coal and pseudo-anthracite found along the northern margin of the Folded Belt in the Laingsburg, Beaufort West and Fraserburg districts of the Cape Province.

According to A. W. Rogers, the testing of this belt would involve the putting down of a number of boreholes to a depth of not less than 6,000 feet. Even if the veins referred to are the residual products of oil seeping upward from pools below the area in which they occur, the uncertainty whether any of these pools still contain oil, and if so, in paying quantities, would make the sinking of very costly bores a highly speculative venture.

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3. Special table prepared by W. J. Wybergh and other information received from the Department of Mines of the Union of South Africa.



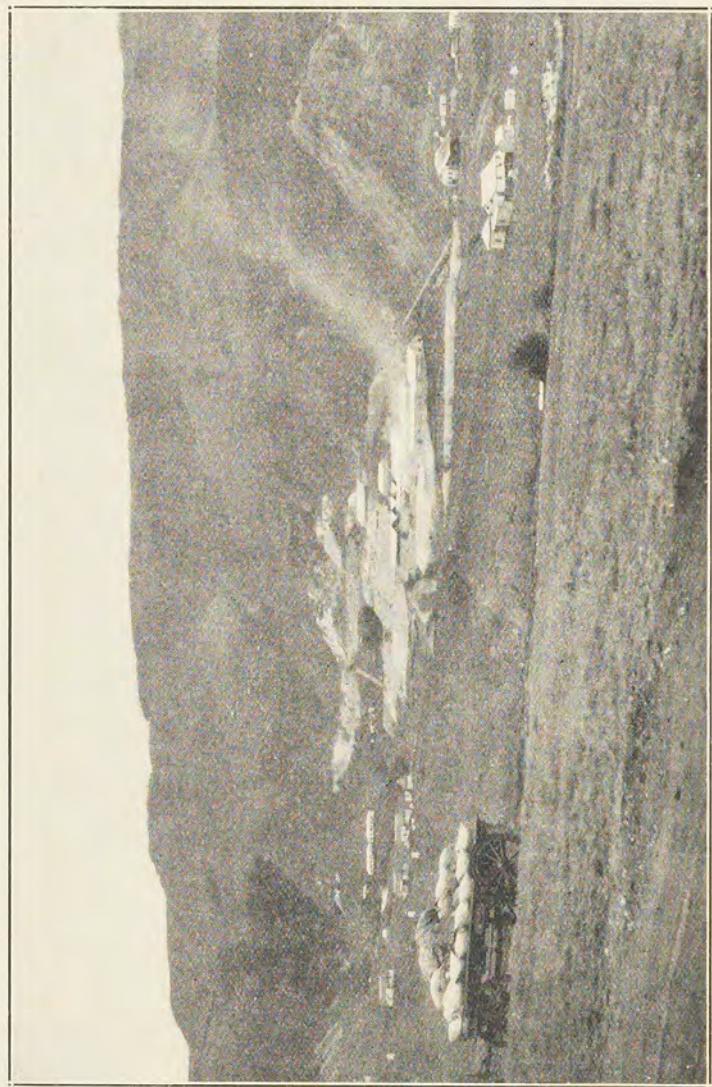


Plate XXIX.—The New Amanthus mine, Kaapsche Hoop.
[Photo, Publicity Dept., S.A. Railways.]

CHAPTER IX

OTHER NON-METALLIC MINERALS.

Of the mineral deposits described in this chapter, the annual production of structural products made or derived from stone, sand and clay are of far greater value than any of the others. Asbestos comes next, the salt group—soda, common salt and gypsum—third and after them corundum, fluorspar and mica. The production of talc, magnesite, graphite, arsenic, etc., is very small. The probable future development of certain of these minerals is referred to in Chapter II.

The location of deposits of non-metallic minerals that have been exploited is shown on the map, figure 21, but with the exception of certain deposits of marble and limestone, deposits of stone, sand and clay are not indicated.

ASBESTOS

The asbestos industry of South Africa, although not of great magnitude, is of interest in that it has added two more minerals to the world's spinnable and fire resisting materials. They are the amphiboles crocidolite, or "Cape blue," and amosite, or "Cape white," asbestos.

Asbestos mining began in 1893 when the Cape Asbestos Company produced nearly 100 tons of crocidolite. Chrysotile was first produced in 1906 and amosite in 1912. In recent years there has been a rapid increase in the output of asbestos and the development of the industry. During 1928 there were produced 12,162 tons of chrysotile asbestos, 5,144 tons of crocidolite, and 6,748 tons of amosite; a total of 24,054 tons.

Five classes of asbestos occur within the Union. They are: chrysotile, crocidolite, amosite, tremolite and asbestic. Only the first three are being exploited.

CHRYSOTILE

Chrysotile occurs in basic rocks of the Jamestown series of the Swaziland system on Joubertsdal 99, three miles north of Kaapsche Hoop and 28 miles in a straight line north-west of Barberton; on Kalkkloof 250, in the Carolina district about 33 miles as the crow flies west by south of Barberton; at Havelock mine in Swaziland; and in numerous other places in the Transvaal and in Natal where rocks of this character crop out. Chrysotile occurs also in serpentinized dolomites of the Dolomite series on the

farms Rietfontein 70, Goedverwacht 32, Silverkop 31 and Diepgezet 33, about 25 miles by road east of Carolina, and in several other localities where the dolomites crop out.

Chrysotile is a fibrous variety of serpentine, a magnesium silicate $H_4Mg_3SiO_2O_6$. It is a white to greenish and yellowish white mineral, and has the property of separating into fibres of exceedingly fine diameter. Its two most important characteristics are spinnability and resistance to heat. Spinnability is determined by the length of the fibre, its fineness, flexibility, resilience and tensile strength. Fibre of good quality is valued by its length. Good chrysotile withstands temperatures of from 2,000 to 3,000 C. without fusing, but loses some of its water of crystallization and becomes brittle at a lower temperature. It is a poor conductor of heat and electricity. Chrysotile invariably occurs in serpentine and usually in "cross-fibre" veins, that is veins in which the long axes of the fibres are arranged at right angles to the length of the vein. In places the fibres lie at an angle to the length of the vein; and along shear planes and faults, so-called "slip fibre" occurs lying with the strands parallel to the fracture plane or vein.

Deposits in the Jamestown Series

The chrysotile on Joubertsdal 99 occurs in a belt of serpentine and allied basic rock occupying a ridge in the De Kaap valley. The serpentines pass westward under the horizontal quartzites at the edge of the Drakensberg. The serpentine is made up of broad alternate bands of blue and green varieties. The green serpentine, which carries the asbestos is composed of pale green rock weathering black. In places its fresh fracture is smooth, in others it has a granular appearance. The blue which overlies the green at the workings is a blue-grey rock with a rough texture on the fresh surface. Hall believes that the green serpentine is derived from a rock that consisted dominantly of olivine and the blue from one in which there was originally a large percentage of pyroxene or amphibole.

The serpentine belt has a maximum width of about two miles, and fibre has been proved to extend along it for not less than three miles. There is a westerly section lying on the eastern slopes of the Drakensberg, that reaches from a small stream cutting across the serpentine westwards until it disappears under the Drakensberg escarpment. Within this portion fall the workings of New Amianthus,

Ltd., on the northern portion of Joubertsdal 99, and those of Kaapsche Hoop Chrysotile, Ltd., on the southern portion of the same farm. (Plate XXIX.)

There are two distinct fibre horizons, known as the Griffin Line and the Ribbon Line.

The Griffin Line has been followed for about 800 yards and shows a large number of roughly parallel cross-fibre seams distributed through a maximum thickness of 15 feet of green serpentine parallel to and within 15 feet of its contact with a dark grey or "blue" serpentine.

The distribution of the Ribbon Line coincides with that of a well-defined thin quartzite from which the Ribbon Line extends for a variable thickness up to 15 feet downwards into the underlying serpentine. The deposit, which dips from 10 to 20 degrees, is opened up by a series of adits and drives on two levels with a vertical interval of 70 feet. Over not less than 450 yards along the strike a very large number of parallel seams of chrysotile lie in the serpentine. The fibre belt usually varies from 5 to 7 feet in width. Its upper portion over some 2 feet up to the hanging wall consists of "Ribbon" rock, i.e., serpentine in which many thin parallel seams of fibre are spaced closely together, 15 to 30 seams per linear foot being quite common. The lower 3 to 5 feet consist of fewer, but thicker, seams spaced at greater intervals. Over the former section the recovery of chrysotile is consistently in the neighbourhood of 30 per cent., while over the latter in the best sections of the mine it is about 10 per cent. for distances up to 300 feet along the strike.

The fibre from this source is of excellent quality and is now well established in the market. The character of the chrysotile is well maintained down to the lowest depth reached, which is 600 feet vertically below the surface. The proportion of fibre over 1 inch in length is approximately 5 per cent.

In the eastern section a series of fibre deposits is being worked by Munnik-Myburgh Asbestos, Ltd., on the Government ground Uitkyk and Sunnyside, adjoining Joubertsdal on the south. These deposits lie in the identical belt of serpentine, and are no doubt a direct continuation of the Griffin Line, with a class of fibre similar in appearance and quality to that produced in the western section.

There are four more or less parallel zones of asbestos-bearing serpentine, varying between 2 and 7 feet in thickness, and giving a combined length of fibre horizon

of about $2\frac{1}{2}$ miles, of which only some 2,000 feet have so far been opened up.

Individual veins are lens-like and vary much in the length of fibre they contain. The average lengths produced in mining vary also according to whether methods of recovery allow of the winning of the shorter grades of fibre. The following results of one month's output at one of the mines, although it was determined some years ago, will serve to indicate the percentages of the various lengths of fibre present in the rock: Over $2\frac{1}{2}$ inches, hand-cobbed, 1.80 per cent.; $1\frac{1}{2}$ to $2\frac{1}{2}$ inches, hand-cobbed, 3.04 per cent.; $1\frac{1}{8}$ to $1\frac{1}{2}$ inches, hand-cobbed, 3.40 per cent.; over $\frac{5}{8}$ inches, screened, 24.30 per cent.; $\frac{1}{4}$ to $\frac{5}{8}$ inches screened, 40.20 per cent.; $\frac{1}{4}$ to $\frac{1}{2}$ inches, machine milled, 27.50 per cent.

The Kalkkloof chrysotile occurrences also lie at the contact of green and blue serpentine and the veins are for the most part in the green rock.

Deposits in the Dolomite Series

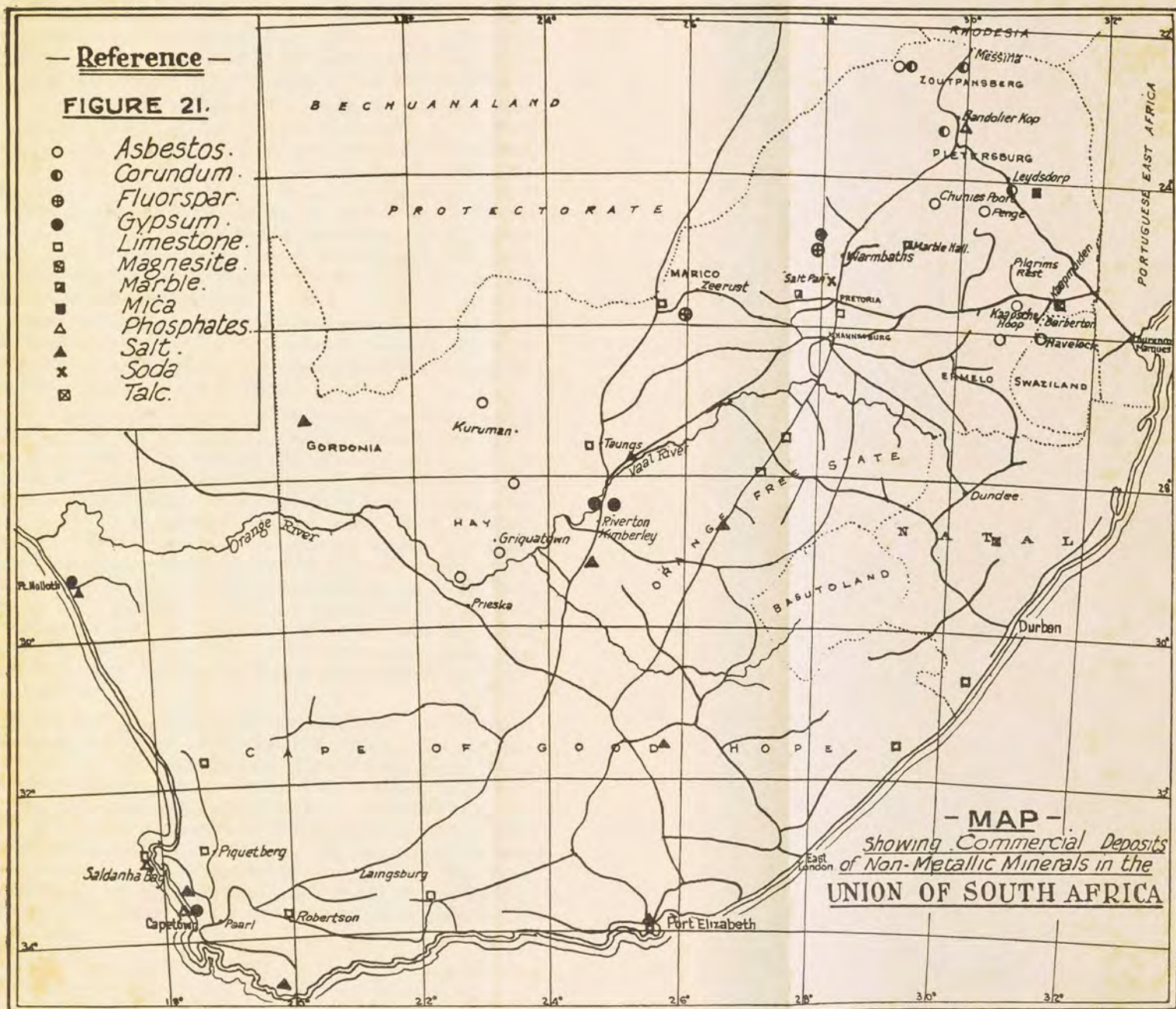
In the occurrences near Carolina chrysotile is found in serpentinized dolomite occurring within a few feet of the contact of several dolerite sills that lie in the dolomite at horizons close under the base of the Pretoria series. The fibre is found in places along twenty miles of outcrop of these beds. The veins are lens-like and lie approximately parallel to the bedding of the dolomites. Serpentinization of the dolomite and the formation of the chrysotile are evidently due to contact metamorphism of the dolomite by the intrusive sills.

The deposits were worked from 1905 to 1909, from 1913 to 1914, and at intervals later on. Although the fibre is of excellent quality, the veins are not continuous over any distance and payable bodies are limited in their extent.

CROCIDOLITE

Crocidolite asbestos occurs in Griqualand West at intervals within a line of hills that stretches from 30 miles south of Prieska, on the Orange River, northward through Griquatown and Kuruman to the Bechuanaland border a distance of 250 miles. It is found also in the Haenertsburg gold fields and Malips River portions of the Pietersburg district.

Crocidolite is an amphibole consisting essentially of ferrous iron and silica, with some sodium oxide and smaller





proportions of the oxides of magnesium and calcium $\text{NaFe}(\text{SiO}_3)_2 \text{FeSiO}_3$. The colour is blue varying in shade. Good commercial crocidolite works up easily into a mass of fibres that are flexible and have a silky feel. Its tensile strength is greater than that of chrysotile and it withstands acid and sea-water better, but fuses at lower temperatures.

In Griqualand West crocidolite occurs in cross-fibre veins of lenticular shape. The veins vary in width up to about 3 inches but probably 70 to 90 per cent. of the asbestos in the rock is less than one half inch in length. In places the vein is blue and has a fibrous appearance, but is "stoney," that is, it consists in part only of fibrous material. Yellow fibrous-looking material called "tiger eye" that is quite hard, cannot be fiberized, and from its occurrence is evidently a silicified product of blue asbestos is also encountered.

There are places where the asbestos is altered to a soft brown-clay mass, quite evidently as the result of oxidation by surface waters, in other places again perfectly fresh fibre occurs at the surface.

In this district the crocidolite occurs in thin bedded ironstones of the Griquatown series. This series corresponds to the lower part of the Pretoria series of the Transvaal. In places the ironstones are disturbed by local contortions and sharp folds and there is a tendency for the crocidolite to develop in the crests of these folds, although deposits are also encountered in less disturbed rocks. All of the individual deposits in this area are small, and in spite of very thorough prospecting, workings that produce over 20 tons of fibre per month are few. There is more continuity in the zones of asbestos to the south of Griquatown village than northwards, but along the northern section the length of fibre encountered is on the whole better.

In the Pietersburg fields the crocidolite occurs in banded ironstones at the base of the Pretoria series. The lens-like shape of the veins and general character are much as in Griqualand West. The quality of fibre is not on the whole as good. The asbestos is inclined to be harsh and brittle, and there is a larger proportion of fibrous-looking vein matter that is stony and will not fiberize. In places there is also a large content of fine grains of magnetite in the veins which break up the fibre and are difficult to get rid of. One mine has been worked successfully on a small scale in this area.

AMOSITE

Amosite asbestos occurs at intervals along the Olifants River between Chuniespoort, south of Pietersburg, to the Steelpoort River north of Lydenburg over a distance of about 60 miles. (Figure 21.)

Amosite is an amphibole composed essentially of ferrous iron and silica with variable quantities of alumina magnesia, lime and soda. The colour is white to yellowish grey and pale green, working up to white fibre. The fibre is not on the whole as fine as in chrysotile. Its tensile strength and resistance to acids and sea water are better than chrysotile. It fuses less readily than crocidolite. Amosite occurs in cross-fibre veins only.

The amosite veins lie in banded ironstones of the Pretoria series or within bands of ironstone that are intercalated in the underlying dolomite. The amosite is confined to the lower 200 feet of the Pretoria series. The main fibre zone worked at Penge lies about 300 feet above the main Dolomite series. Here there are three series of seams, the middle one of which is the main source of asbestos, with a series 7 feet over it and one 10 feet under it. The average length of fibre from the middle seam at Penge mine is from 8 to 9 inches with a maximum of 12 inches. Farther north-west from Penge amosite occurs at three horizons, each about 100 feet in section from the other, the top one of which carries the longest fibre, the maximum length being 4 inches.

TREMOLITE AND ASBESTIC

Occurrences of tremolite are found near Pomeroy in Zululand. Asbestic, a matted deposit of fibres of anthophyllite occurs on Korea, 50 miles west of Waterpoort siding, in the Zoutpansberg district of the Transvaal. They are not being worked.

METHODS OF MINING

In the rugged country in which chrysotile occurs in the eastern Transvaal and crocidolite and amosite in the Lydenburg-Pietersburg area it is possible to open up large portions of the deposits by adits driven to tap them at depth. This, of course, makes for economy in drainage and in the handling of broken rock. In Griqualand West, where the deposits of crocidolite are in most places of limited extent, mining is done by the local natives, who work in some cases directly under white supervision, and in others on their own. These people literally burrow along seams

of crocidolite into the hills. They work either open-cast or by underground methods filling the workings behind them with broken rock as they proceed. Unless under the direction of a white man there is no attempt to develop on a system, or in fact to develop at all. The tendency is to work out rich patches only and discard more or less everything under $\frac{1}{2}$ an inch in length. The fibre as it comes out is hand-cobbed by women and children and bagged. The coloured miners, where not under full time white supervision are helped by the advancing of stores and cash, and are then paid for the weighed quantities of fibre they produce.

PREPARATION OF THE FIBRE

The general process of preparing the three principal grades of asbestos for the market is very similar. When mechanical means are not available veins of fibre are separated from adhering rock by hand-cobbing. The asbestos is fiberized by pounding it with hammers, and is then classified into lengths by passing through screens of the trommel type. Where a mill has been put up the material from the mine is first crushed coarse in a jaw crusher, or in rolls, and the long fibre is then sorted out on a belt. The fine material from the belt goes to finer roll crushers, and from there it passes through a disintegrator or fiberizer where it is worked up into fibre. Shaking screens with vacuum suction, cyclone collectors and grading machines clean and classify the fiberized product after which it is bagged and shipped to the market.

The bagged product of the New Amianthus mine at Joubertsdal 99 amounting to about 1,000 tons per month is transported by means of an aerial tramway over $7\frac{1}{2}$ miles of very rugged country to Elandshoek station on the Pretoria-Lourenço Marques railway.

PRICES

Market prices vary according to the type of asbestos and length of fibre. The average prices received for chrysotile are generally somewhat higher than for crocidolite of the same lengths, and the crocidolite prices are better than for equal lengths of amosite.

In the following table are given the percentages of various lengths of fibre present and the prices obtained for each length in one lot of crocidolite sold at Kuruman some years ago.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

Per Ton.

E.S., fibre over $1\frac{1}{4}$ inches in length, 1.5% ... £84 0 0
 No. 1, fibre $\frac{3}{8}$ to $1\frac{1}{4}$ inches in length, 4.6% ... 64 0 0
 No. 2, fibre $\frac{3}{8}$ to $\frac{3}{4}$ inch in length, 55.0% ... 31 0 0
 No. 3, fibre up to $\frac{3}{8}$ inch in length, 29.3% ... 18 0 0
 the average price for the lot working out at £28 12s. 8d. per ton which is above the average for fibre sold at that time. This crocidolite was produced by hand-cobbing with a consequent waste of the finer material, that would be saved in milling. The market for very short chrysotile fibre is better at the present time than for crocidolite and amosite, and this enables a greater percentage of the fibre present in the chrysotile deposits to be saved and sold than is the case with crocidolite and amosite. Although the average price per ton is depressed by the saving of the fine fibre the ultimate profit tends, of course, to be greater.

PRODUCTION

The total value of asbestos produced in the Union up to the end of 1928, as given in official returns, amounts to £2,177,949, and the following table gives the output year by year for each province since 1911:—

UNION OF SOUTH AFRICA

Year.	Cape.		Natal.		Transvaal.		Union of South Africa.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
	£		£		£		£	
1911	1,253	20,765	13	74	—	—	1,266	20,839
1912	1,217	18,892	3	60	—	—	1,220	18,882
1913	938	15,599	24	429	—	—	962	16,028
1914	1,160	18,657	—	—	30	1,430	1,190	20,087
1915	2,083	33,166	—	—	56	2,733	2,139	35,899
1916	4,228	74,293	21	287	407	8,490	4,656	83,070
1917	2,999	49,485	28	393	3,193	37,486	6,220	87,364
1918	2,739	44,148	5	60	930	9,829	3,674	54,037
1919	3,204	57,578	97	1,149	631	7,699	3,932	66,426
1920	3,526	71,875	45	1,137	3,541	41,183	7,112	114,195
1921	3,467	74,489	62	1,032	1,593	27,546	5,122	103,067
1922	2,991	55,290	6	44	1,392	25,896	4,389	81,230
1923	4,317	55,063	—	—	4,076	66,390	8,393	121,453
1924	3,002	38,370	—	—	4,239	71,705	7,241	110,075
1925	2,541	42,108	—	—	7,627	110,007	10,168	152,115
1926	3,993	80,656	—	—	10,104	135,810	14,097	216,466
1927	4,827	106,446	—	—	17,313	236,855	22,140	343,301
1928	5,077	113,400	—	—	18,977	286,150	24,054	399,550

The different classes of asbestos produced in recent years and their values, according to official returns, are as shown hereunder:—

OTHER NON-METALLIC MINERALS

UNION OF SOUTH AFRICA

Province.	Year.	Amosite.		Chrysotile.		Crocidolite.		Total.	
		Tons.	Value. £	Tons.	Value. £	Tons.	Value. £	Tons.	Value. £
Transvaal	1926 ...	2,940	28,755	7,133	105,876	31	1,179	10,104	135,810
	1927 ...	5,093	50,319	12,174	184,897	46	1,639	17,313	236,855
	1928 ...	6,749	69,039	12,162	214,866	66	2,215	18,977	286,150
Cape ...	1926 ...	—	—	—	—	3,993	80,656	3,993	80,656
	1927 ...	—	—	—	—	4,827	106,446	4,827	106,446
	1928 ...	—	—	—	—	5,077	113,400	5,077	113,400
Natal ...	1926 ...	—	—	—	—	—	—	—	—
	1927 ...	—	—	—	—	—	—	—	—
	1928 ...	—	—	—	—	—	—	—	—
Total ...	1926 ...	2,940	28,755	7,133	105,876	4,023	81,835	14,097	216,466
	1927 ...	5,093	50,319	12,174	184,897	4,873	108,085	22,140	343,301
	1928 ...	6,749	69,039	12,162	214,866	5,143	115,615	24,054	399,550

FUTURE PRODUCTION

In the eastern Transvaal, Swaziland, and Natal there are extensive areas underlain by serpentinized basic rocks similar to those in which the New Amianthus and Kalkkloof chrysotile asbestos are found. There is, therefore, the possibility of discovering other deposits of commercial value, and it seems probable that the production of chrysotile will increase in the future.

The deposits of crocidolite so far discovered in Griqualand West are individually small but the aggregate tonnage present over a length of 260 miles must be very great. There will probably be a fairly constant production of a small tonnage from this area for many years to come. The crocidolite deposits in Pietersburg have not developed in a very encouraging manner up to the present. Outside of the ground on which crocidolite is known there are, however, large areas in which the ironstones that occur near the base of the Pretoria series outcrop and there is therefore a chance of other deposits being discovered.

Excepting the amosite of the Penge mining area, where a very large tonnage is indicated, development of amosite occurrences in the Lydenburg-Pietersburg belt is not far enough advanced to judge of the extent of the deposits.

BARYTES

There are important deposits of this mineral near Riversdale in the Cape Province, and it occurs in veins on the farm Vergelegen 1695 on the Magalakwin River, 80 miles north-west of Pietersburg in the Transvaal. There are no records of its having been produced in the Union.

CORUNDUM

The Transvaal possesses the richest and most extensive corundum fields in the world. Production in the Union commenced in 1912 reaching a period of great activity at the end of the war and again in 1926. The fields cover an area of 2,000 square miles in the northern and north-eastern parts of the Province, and embrace two distinct tracts of country. These are a northern tract lying in the Zoutpansberg district athwart the Pietersburg-Messina railway, the industry being centred about Bandolier Kop and Mara; and an eastern tract situated in the "Low" country south and east of Leydsdorp, and practically co-extensive with the Olifants River mica fields. (Figure 21.)

The occurrences are of two main types, namely (1) primary, and (2) eluvial.

1. In the primary occurrences corundum in well-shaped crystals and aggregates of interlocking anhedral forms occurs as a constituent of irregular vertical intrusions of plumasite pegmatite, the mineral being concentrated in the peripheral parts of the intrusions. The bodies of plumasite pegmatite are up to 12 feet thick and carry from 12 to 60 per cent. of corundum. They are intrusive in peridotites, pyroxenites and basic schists (Plate XXX.) which are also invaded by gneiss-granite. Where a pegmatite body is followed from the basic rocks into the granite it ceases to bear corundum and becomes an ordinary quartz-feldspar pegmatite. The ultrabasic rocks are altered along their contacts with the corundiferous pegmatite the commonest alteration product being talc.

2. The eluvial deposits consist of extensive, shallow, residual surface accumulations of corundum crystals (crystal corundum) accompanied by scattered lumps of corundum-rich feldspar rock (boulder corundum) derived from the disintegration of bodies of plumasite. They cover considerable areas, and have been the source of most of the corundum so far exported from South Africa. It is worth noting, however, that the "grain" corundum prepared by crushing and concentrating plumasite has been proved by tests carried out in the United States to be a much better abrasive than the crushed crystal corundum.

The percentage of alumina in crystal corundum is from 94 to 96 per cent. and in boulder corundum 60 to 80 per cent. Small quantities of corundum have also been recovered at intervals from the neighbourhood of Steinkopf in Namaqualand where the mineral occurs as a constituent of corundum gneiss.



Plate XXX.—Corundum bearing plumasite vein or dyke contact of intruded
serpentine on left, Zoutpansberg district.

[Photo, A. L. Hall.]



Crystal and boulder corundum have been won entirely by the primitive open-cast pick and shovel method of mining and hand washing. The methods of recovery are not dissimilar to alluvial diamond washing. The gravels are sieved and the concentrates so obtained is washed and cleaned. Concentrated product is screened to definite sizes and such classification together with its appearance are the important factors in grading the material for the market.

A small beginning has been made in the production of grain corundum by crushing the "reef" corundum, which contains about 40 per cent. of corundum, and concentrating the crushed product.

The following table shows the output of corundum from the Union from 1914 to the end of 1928 in tons of 2,000 lb.:—

Year	Tons	Year	Tons	Year	Tons
1914 ...	12	1919 ...	179	1924 ...	1,868
1915 ...	68	1920 ...	260	1925 ...	1,832
1916 ...	755	1921 ...	123	1926 ...	5,996
1917 ...	2,629	1922 ...	2,024	1927 ...	1,064
1918 ...	3,876	1923 ...	2,815	1928 ...	2,019

DIATOMACEOUS EARTH (KIESELGUHR).

Kieselguhr has a wide distribution in the Ermelo district of the Transvaal and in Griqualand West, Gordonia and the Bechuanaland Protectorate. In the Ermelo district it occurs as a rule as a black peaty deposit occupying the beds of small fresh-water marshes. The most important deposit is on the farm Bankplaats 87, situated 12 miles north-west of Sheepmore siding. It has been worked to a small extent at different times, white kieselguhr of great purity being obtained by calcining the peaty matter.

In Griqualand West and the other areas named kieselguhr occurs in shallow pans in association with calcareous tufa.

FLUORSPAR

The Union of South Africa has in recent years become an important producer of fluorspar. The mineral is derived mainly from the Marico district of the Transvaal, where it occurs in pipe-shaped and irregular replacement deposits, in the dolomite series of the Transvaal system. These are very closely related to the zinc and lead deposits of that area, to which reference has already been made.

The most important deposit is situated on the farm Oog van Malmani 101, about 15 miles south of Zeerust. It is a funnel-shaped pipe in somewhat disturbed dolomite and chert. It measured 120 x 120 feet at the surface; at 40 feet the dimensions had decreased to 80 x 60 feet, and at a depth of 85 feet it passed downward into a number of irregular fluorspar veins. The pipe-shaped portion of the deposit is occupied in its peripheral part by greyish and purple fluorspar enclosing isolated patches of galena, zincblende, pyrrhotite and calcite. The interior was occupied by pure colourless spar some of which was considered good enough for optical purposes and realized 10 shillings per ounce in London. The ordinary "run of mine" fluorspar is also of exceptional purity, some of the shipments having averaged 99.4 per cent. of CaF_2 . The dolomite surrounding the pipe is much altered and is unusually rich in talc, which appears here to take the place of the tremolite surrounding the Witkop zinc pipe.

There are less important fluorspar deposits in the same area on the farms Buffelshoek 284, Naauwpoort 102 and Strydfontein 267.

Fairly considerable quantities of fluorspar have been recovered from flat-dipping veins of pegmatite in Bushveld granite south-west of Warmbaths in the Transvaal.

The production in 1927 was 8,358 tons, valued at £16,536; and in 1928, 6,153 tons, valued at £12,086.

GRAPHITE

The value of the total graphite produced in the Union is given as £32,506.

Only one workable deposit of graphite has so far been discovered in South Africa. This is situated on the farm Goedehoop 223, twenty miles east of Groot Spelonken siding in the Zoutpansberg district of the Transvaal. It takes the form of a lens with an average thickness of about 10 feet, formed mainly of amorphous or massive graphite which is interspersed with patches and traversed by veinlets of flake- and columnar-graphite. The footwall of the deposit is formed by decomposed pyroxenite, and the hanging-wall by schistose quartzite, striking east and west and dipping 55 degrees to the south. The graphite lens conforms in dip and strike to the quartzite.

The amorphous graphite is said to be of suitable quality for the manufacture of lead pencils and the flake graphite

for the manufacture of crucibles. There is a number of deposits of impure graphite in the Transvaal and Natal.

The output in 1927 was 64,294 tons and 55,602 tons in 1928.

GYPSUM

Gypsum used mainly as a retarder in portland cement manufacture, and also to some extent for water purification and manufacture of plaster of paris, is quarried in fairly considerable quantities in the Union.

The principal deposits are situated in Griqualand West and the adjacent north-western portion of the Orange Free State. Here the mineral occurs at many localities in seams and beds of loose crystals, or in irregular masses in superficial deposits of clay, silt and sand probably occupying old pans and "vleis," the gypsum having evidently been deposited from surface waters. Much of it could be derived from ground water where it was formed by the action of oxygenated water on pyrite and surface limestone. The seams are up to 6 feet in thickness, and there are sometimes several of them above one another. The chief occurrences so far worked are on the farms Gannavlake, near Windsorton Rietpan, near Riverton Road in Griqualand West, and Vrede 16 miles south-east of Boshof in the Orange Free State. There is also a considerable gypsum deposit at Ngobevu in Natal. Gypsum is usually found in the salt pans inland and on the coast. Thus some of the salt pans in the Calvinia division of the Cape Province and near Port Nolloth contain gypsum. A few hundred tons have been turned out as a by-product of salt making. 17,009 tons were produced in 1927 and 16,393 tons in 1928.

MAGNESITE

A number of occurrences of this mineral have been located in the Barberton district of the Transvaal, in the basic and ultrabasic rocks of the Jamestown series. They are being worked at the Budd and Althorpe mines situated near Magnesite siding, which is 8 miles east of Kaapmuiden on the Pretoria-Delagoa Bay railway. At both mines magnesite of the "dense" variety forms an irregular network of veins up to 3 feet in thickness in serpentine. It is of great purity and is used for the manufacture of magnesite bricks. There are similar deposits east and north of Eureka siding on the Barberton railway. (Figure 21.)

There are also important occurrences of magnesite in the ultrabasic rocks of the norite zone of the Bushveld complex in the Lydenburg, Pietersburg, and Marico districts of the Transvaal. Some of this magnesite is pure, but some of it contains a good deal of calcium carbonate.

Magnesite is used for the making of refractory magnesite bricks and for the manufacture of carbon dioxide and of cupels.

Attempts to exploit magnesite began in 1906. The total value of the mineral produced to the end of 1928 is £57,712. 854 tons were produced during the first half of 1929 valued at £1,693.

MICA

Mica of excellent quality is found in the Leydsdorp division of the Pietersburg district of the Transvaal, where there is a well-defined mica belt from two to four miles wide extending in an east and west direction for fifty miles from the neighbourhood of Mica siding to the Portuguese border. The most important deposits lie between the Mashishimala Hills and the Olifants River. The mica which is of the muscovite variety occurs in great dykes and irregular masses of coarse grained white pegmatite following the southern margin of the Palabora granite *massif*. The pegmatite bodies are up to several hundred yards in length and up to 60 feet in width. The muscovite occurs in books and in irregular nests and pockets. As a rule the distribution of the mineral is quite irregular, but occasionally, as at the Godiva mine, it follows more or less definite zones close to the contact of the pegmatite with the surrounding rocks. The muscovite, speaking generally, has a pale-brownish tint, but a soft pale-green variety occurs near Malelane and at other localities in the southern part of the mica belt. The soft green variety is becoming increasingly popular with American consumers who describe it as being particularly useful for grinding into a silvery lustrous powder used in many industries. As in other mica fields the proportion of saleable mica that is produced in the cutting sheds forms only about 5 per cent. of the mica as it comes from the mine. Mining has not so far been successful, but the railway which has been built through the fields may make conditions more favourable to success in the future. The production in 1927 was 1,603,358 tons, 1928 3,768,879 tons, and the first half of 1929 1,471,537 tons, the latter valued at £3,279.

Mica has been worked on a small scale also at Steinkopf in Namaqualand.

MINERAL PAINTS

Pure red and yellow ochre are quarried at Hazeldene situated 15 miles east of Dundee in Natal, the mineral worked being an ochreous phase of a bed of iron ore occurring in the coal measure series of the Karroo system of this locality.

Ochres and mineral paints are also worked at other localities in Natal.

Brown umber of good quality occurs in the dolomite north of Krugersdorp in the Transvaal.

NITRATES

In the Prieska and Hay districts of the Cape Province fairly pure saltpetre, potassium nitrate, occurs as an incrustation, in veins and pockets and impregnating clayey ferruginous matter on cliff faces, and particularly at the base of such cliffs, and in caves and recesses and in other places protected from rain. They are found in scarped ranges of hills built of the banded ferruginous shales and jaspers of the Lower Griquatown series.

The deposits are scattered over a considerable extent of country stretching from Griquatown to 20 miles south-east of Prieska, the nitrate belt being co-extensive with the outcrop of the rocks of the Lower Griquatown series. The deposits owe their origin to a process of nitrification by bacterial action on the excrement of small mammals and birds, the potash having evidently been derived from the shales of the Griquatown series which have been proved to contain appreciable amounts of potassa. Several attempts to work these deposits have failed, but small amounts of nitre are obtained by picking along the cliff faces.

Somewhat similar deposits of calcium nitrate are found on cliffs of dolomite east of Chuniespoort in the Pietersburg district of the Transvaal.

Of a totally different nature is the occurrence of nitrates below the Matsap Pan in the Hay district of Cape Province. Here gritty layers intercalated with clay and shale underlying the pan have been proved to be impregnated with the brine carrying sodium and magnesium sulphate and chloride and notable amounts of sodium nitrate. A process for separating the sodium nitrate by fractional crystallization has been devised, but has not so far been applied on a practical scale.

Deposits of sodium chloride with sodium nitrate and the sulphates of calcium magnesium and sodium occur as efflorescences on cliffs in the Auob valley of South West Africa. They are believed to have originated from briny waters in the underlying Karroo sandstones and shales of Dwyka or Ecca age. Most of the cliffs are of Kalahari limestone, a limestone of continental origin containing much pebble and sandy material in places.

No nitrates are being produced in the Union at the present time.

PHOSPHATES

There are extensive deposits of rock phosphate at Saldanha Bay on the west coast of the Cape Province. The phosphate, an intimate mixture of aluminium and iron phosphate, has been formed mainly by the phosphatization of granite and quartz porphyry detritus and to a less extent by the phosphatization of these rocks *in situ*. An attempt was made in 1918 to work these deposits on a big scale, but it was found that, while the surface crust was fairly rich, the average phosphoric oxide content was too low to admit of the conversion of the phosphate into fertilizer containing sufficient available phosphorus to enable it to compete with imported phosphates.

A small deposit of the more valuable calcium phosphate or phosphorite was found on the Hoetjes Bay Peninsula near Saldanha Bay. (Figure 21.)

Quite recently a promising deposit of phosphatized beach or dune sand has been discovered on Cravens Gift and adjoining farms near Mamre Road station on the line from Kalabas Kraal to Saldanha Bay. It is up to 7 feet thick and analyses indicate up to 25.7 per cent. of P_2O_5 , practically the whole of which is present as calcium phosphate.

Nodules and lenses of phosphate rock containing up to 28 per cent. of P_2O_5 , combined with lime, occur in the upper Dwyka shales near Matjesfontein and other localities in the Laingsburg division of the Cape Province; also in the upper Ecca shales in the Weenen area and elsewhere in Natal. They are, unfortunately, too small and too sparingly distributed to be worthy of exploitation.

At the present time there is being opened up on Spelonken Water 927, Schaapkraal 2622, and adjoining farms, situated 15 miles east of Bandolier Kop in the Zoutpansberg district of the Transvaal, a series of apatite-bearing pegmatite veins. They carry fluor-apatite in the

form of big isolated crystals and in irregular pockets and steeply dipping bands and stringers evidently formed by pneumatolytic action at a slightly later date than the quartz and feldspar which they accompany. The most promising occurrence so far opened up, situated on Spelonken Water 927, has an average width of 3 feet and averages 18 per cent. of P_2O_5 over this width. Some of the other veins are also fairly rich, but the majority do not appear to be worth working.

SALT¹

Though sediments of continental origin are dominant amongst the rocks in the Union and South West Africa no beds of soluble salts have yet been found in them. Most of the salt used in the country is derived from pans, depressions without outlets. In addition salt is derived directly from sea-water in some of the river beds near the west and south coasts, and from salt blown inland and washed down into the coastal pans by rain. The most productive pans are those along a broad belt in the Interior Plateaus, which coincides roughly with the western outcrop of the lower part of the Karroo system from the Calvinia district north-eastwards to the southern Transvaal. In this belt there are many pans, some of which are exploited. A few salt-pans situated on beds much higher in the Karroo sequence, are also worked.

Some of the sediments, of the Karroo and Uitenhage formations, yield water containing appreciable amounts of sodium chloride, that is, common salt. Where such briny waters drain into pans the water evaporates and leaves the salt behind.

The salt in the brines of the lower beds of the Karroo system is presumably of marine origin. This is supported by the discovery of bromides by Parry in the brine of the Riverton salt-pan. Though the beds are not known to contain marine fossils in the Union, they were probably deposited within reach of salt-laden winds from the sea. The presence of such "cyclic" salt in quantity has been proved in the case of the Sambhar Lake 400 miles from the sea in Rajputana (India), and similar explanation of the salts in the Dwyka of the Karroo system and overlying beds is probable. Whether the same explanation holds for the salts in the red strata of the upper Beaufort series is

¹ Contributed by C. J. N. Jourdan, Inspector of Mines, Department of Mines of Union of South Africa.

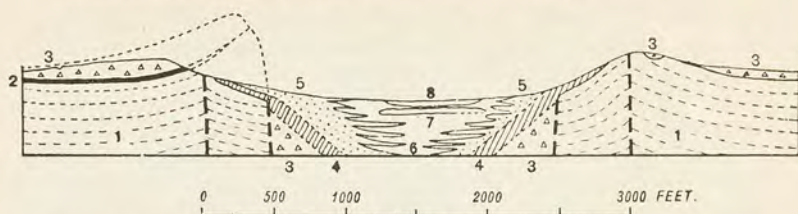


FIGURE 22—Section through the Salt Pan crater, Transvaal.
 1 Granite. 2 Grits. 3 Granite breccia in place. 4 Breccia composed of fallen blocks. 5 Granite detritus. 6 Laminated saline clays. 7 Trona band zone. (After P. A. Wagner.)

doubtful. A pan near Hofmeyr in these beds is productive. The Zwartkops salt-pan near Port Elizabeth probably gets its salt partly from the Uitenhage beds in which it lies and partly from the winds off Algoa Bay. The thick crusts of salt in two pans near the confluence of the Kuruman and Malopo Rivers in the Kalahari are surrounded by country in which superficial Kalahari limestones outcrop, but lower Karroo beds probably underlie the superficial strata.

In the more advanced concerns brine is pumped from shallow pits or boreholes in the pan-floor and the water is removed partly by exposure to the air in shallow pans, and partly by artificial heat. Artificial heat is employed in a few places only. The salt so derived contains notable amount of sodium sulphate in most places. This is removed from the refined grades and left in the others.

According to official statistics the Union imports about 2,700 tons of salt a year and in 1926-27 prepared 88,643 tons valued at £132,272 from its own resources. The latter figure is too low for it refers only to the output of pans worked commercially and does not include the salt collected by farmers from the numerous small salt-pans and from a few coastal lagoons. The value of the salt imported in 1928 was £18,470.

SODA

The only important deposit of sodium carbonate so far discovered in the Union occurs in the Pretoria Salt-pan, 25 miles NNW. of Pretoria. This was an important salt lick and must have been visited by natives and herds of wild game for centuries before white settlement. It was the most important source of common salt for the settlers in the time of the South African Republic. In 1912 it was leased by the Government to P. A. Ogilvie and the manufacture of soda from its brine commenced soon after.

This pan is a crater in Bushveld Red Granite surrounded by a circular rim with a diameter of about 3,400 feet. The tops of the ridges comprising the rim are from 250 to 400 feet above the nearly flat floor of the crater to which they slope steeply. The floor has a diameter of approximately 1,400 feet. Wagner has shown that this depression is a sunken caldera and that the sequence of events in its formation included (a) updoming of the granite, (b) drilling of the vent in a series of volcanic explosions, (c) subsidence of the interior of the volcano with a ring-shaped fault. Boreholes have shown that it is filled with alternate layers of mud and irregular layers of granite breccia (see figure 22). The mud contains brines of sodium chloride together with sodium carbonate and sodium bicarbonate. In the centre of the pan there is from the surface down 18 feet of alternating layers of mud and crystal trona $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$. Below this is the gaylussite layer, from 5 to about 8 feet thick, of coarse layers of crystals of gaylussite $\text{Na}_2\text{CO}_3 \cdot \text{CaCO}_3 \cdot 5\text{H}_2\text{O}$, and nodules of chalcedonic silica, interbedded with and underlain by saline clays and marls. The gaylussite layers are impregnated with clear saturated soda salt brine and above the brine methane gas usually exists under pressure. It is upon this brine that the soda industry at the pan is based. Below the gaylussite layer are saline muds containing some trona and gaylussite. The origin of the soda and salt are ascribed to volcanic vapours and solutions. A soda lake existed in the crater, but was completely dried up before the present climatic period.

EXPLOITATION

Boreholes to depths of about 30 feet have been sunk at intervals over the floor of the pan to tap the brine in the gaylussite layer. From these a solution containing approximately 9 per cent. of sodium chloride, 5.6 per cent. of sodium carbonate and subordinate amounts of sodium bicarbonate is pumped to a reservoir on the rim of the pan from where it gravitates to the treatment plant. From there it goes to a triple effect evaporator. The saturated brine from the evaporator is first cooled to atmospheric temperature in a cooling tower, thereafter precooled to 60° Fah. and then cooled in a refrigerating plant to a temperature of 20° Fah. Refrigeration is carried out in concrete tanks by ammonia as in cold storage practice. During the process washing soda, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, crystallizes out and sodium chloride stays in solution. The mixture of crystals

and salt is pumped to hydro-extractors and there separated. The crystals of washing soda or decahydrate containing 33 per cent. anhydrous sodium carbonate and 2 per cent sodium chloride are sent to a vacuum pan, where monohydrate is formed containing 80 per cent. of anhydrous sodium carbonate and 1 per cent. of sodium chloride. This is separated from the decahydrate in a hydro-extractor and subsequently dried in a calciner leaving soda ash containing 97 per cent. of anhydrous sodium carbonate.

The total value of the soda produced in the Union up to the end of 1928 is given as £210,981. All of this was presumably derived from this locality. The output during 1927 was 2,893.5 tons, valued at £32,710; 1928, 2,661.5 tons valued at £30,127; and the first 6 months of 1929, 1,196 tons, valued at £14,127.

Wagner, in what he refers to as a rough approximation, estimated that in 1922 there was available 350,000 tons of soda and 580,000 tons of common salt in the pan within 94 feet of the surface and in addition 29,000 tons of trona.

STRUCTURAL MATERIALS.

Under this head are included stone, gravel, sand and clay.

The gross value of articles manufactured in the Union in the year 1926-1927 from stone, including dressed stone and slate, and the products of lime and cement factories, from clay and from sand including glass, etc., was valued at £3,208,721. The value of the raw materials used was £661,011 of which only £295,987 was of South African origin. The total value of such structural materials is undoubtedly greater than the official returns indicate, for much of the stone and gravel excavated and used locally for purposes of building and road construction must go unrecorded. The figures indicate that the value of the annual output of these products in the Union is comparable with that of coal and is far greater than that of any other mineral product outside of gold, diamonds and coal.

Except in the case of limestones there has been no systematic survey of deposits of these common materials and no laboratories are in existence in which adequate physical tests can be made on building stones, concrete aggregates, road-metal aggregates and clays. That such field and laboratory investigation is needed is indicated by the fact that less than 50 per cent. of the material used in the factories referred to is of South African origin.

STONE

Granite

Several varieties of the Old Grey Granite are quarried for building stone between Johannesburg and Pretoria, the best known is that obtained at Witkoppen, 14 miles north of Johannesburg. This is a medium-grained biotite granite with barely perceptible foliation. It has a very high crushing strength, and is on this account largely used for the foundations of public buildings, bridges and the like. A very handsome pale yellowish-grey variety of the Old Granite is quarried at Pietersburg.

The Paarl granite, so much in evidence near the town of that name, is extensively used in the Cape Province and also to some extent in the Transvaal.

Syenite

The Southern Transvaal probably stands unrivalled in the variety of beautiful syenites which it contains. A start has been made to use them for ornamental purposes, and as they become better known, they will doubtless be in great demand. Syenite on the farm Leeuwfontein 320 near Hatherley Station in the Pretoria district has been quarried.

Norite

A rather dark-coloured variety of the norite of the Bushveld complex is quarried on a considerable scale at Bon Accord, 8 miles north of Pretoria; it is very largely used for shop fronts, tombstones, curbing and also to some extent for building purposes. Conditions are favourable for cheap quarrying and the available supply is very large. This when crushed should make a fair stone for water bound macadam roads.

Dolerite and Diabase

These rocks which are very widely distributed have been utilized to some extent for building purposes, but their sombre appearance militates against their more general use. Diabase when crushed and sized is the best type of stone that can be used for road metal or concrete aggregates.

Limestone and Dolomite

The Union is, on the whole, rather poorly off in limestone suitable for industrial purposes, but has vast resources of pure dolomite. Dolomite is being utilized to a limited extent for the production of what is known as "blue lime," but is to be used on a large scale as a flux

in the iron works which it is proposed to erect at Pretoria. It is apparently not used very extensively for building stone.

The limestones proper fall into two main categories, namely:—

1. Primary limestones;
2. Secondary limestones.

Primary Limestones

The most important deposits under this heading are the marbles on the farms Marble Hall 248, and Scherp Arabie 367, in the north-eastern part of the Pretoria district; a broad belt of pure crystalline limestone on the farm Inkom 1727 in the northern part of the Zoutpansberg district, Transvaal; occurrences of crystalline limestone belonging to the Malmesbury series in the Robertson, Piquetberg and Van Rhynsdorp divisions of the Cape Province; and near Hankey and Patentie in the Humansdorp division of the same Province.

With the exception of the deposits near Piquetberg, which are being worked by the Cape Portland Cement Company, all these occurrences are unfortunately too inaccessible at the present time to be of commercial value.

Secondary Limestones

These have a very wide distribution in South Africa and are very largely used for the production of lime and cement. They are of four main types, namely:—

- (a) Cliff travertine and allied varieties;
- (b) Vlei limestones;
- (c) Surface limestone proper;
- (d) Cave limestone.

(a) The principal deposits of cliff travertine are situated along the eastern escarpment of the Kaap Plateau in Bechuanaland. That at Buxton, 7 miles south-east of Taungs, has been worked for some years and is of great magnitude. It consists mainly of calcareous tufa, of the cliff travertine variety, occupying an ancient river channel where it widened out on leaving the Kaap Plateau and entered the broad valley of the Harts River. The limestone is of exceptional purity. About 6 miles to the south is another great deposit following the edge of the Kaap Plateau. The deposits near Taungs are estimated to contain seven million tons of limestone.

(b) Vlei limestone usually consists of fine white or grey chalky material enclosing porous lumps and masses

of tufa. It has clearly resulted from the precipitation of calcium carbonate from more or less stagnant or slowly moving water by swampy vegetation. There are important deposits of this type of limestone on Paardevallei and adjoining farms in the Marico district of the Transvaal.

(c) Surface limestone proper consists of solid sheets or layers composed of nodular concretions of calcium carbonate of varying degrees of purity formed by the slow rise to the surface by capillary action and its evaporation there of lime bearing water. The sheets are up to 100 feet thick. The limestone is sometimes pure, but generally contains a good deal of silica in the form of sand. Thus, the surface limestone quarried by the Pretoria Portland Cement Company, 5 miles east-north-east of Pienaars River in the Transvaal contains up to 15 per cent. of silica.

There are very extensive deposits of surface limestone in the central and western Transvaal and in the Winburg and adjoining districts of the Orange Free State.

(d) Cave Limestone consists of stalactites and stalagmites of irregular banded sheets composed mostly of acicular crystals of aragonite. The deposits are as a rule of limited extent, but yield lime of exceptional purity. Such cave limestone is worked at Makapan's Gat north of Potgietersrust in the Transvaal.

Reference may also be made to an important occurrence of limestone situated at Uitloop, north of Potgietersrust, which has resulted from the de-dolomitization under rather peculiar circumstances of the dolomite of the Transvaal system.

The value of the output of lime works in the Union rose from £217,833 in 1924-25 to £261,183 in 1926-27.

Marble

There are very important deposits of white and several types of coloured marble on the farms Marble Hall 248 and Scherp Arabie 367, situated in the Bushveld about 100 miles north-east of Pretoria. Some of this has been used for statuary, with fair results, and yields a very pure lime suitable for metallurgical use. Recently deposits of fancy marble of various colours and patterns have been discovered on the farm Buffelspoort 370, situated 30 miles north of Brits in the Transvaal.

There are also deposits of bluish-grey, grey and yellowish marble in the Malmesbury beds in the Van Rhynsdorp district north of Capetown. One of them on

the farm Klipdrift, situated on the Holle River, a tributary of the Olifants, is being worked.

Sandstone

The Ecca and Stormberg series of the Karroo system yield many varieties of sandstone. The best and most reliable of these is that quarried at Flatpan, situated near Coalbrook in the northern Orange Free State. It is a freestone of dull grey or bluish-grey colour and of pleasing appearance. It is seen to great advantage in the upper storeys of the Union Building, Pretoria. Rather less satisfactory sandstone is quarried at Steenpan which adjoins Flatpan, and at Klippan in the same neighbourhood.

Sandstone is also quarried at many other localities in the Transvaal and Orange Free State. One of the most handsome varieties is that outcropping on the sides of Buiskop near Warmbaths.

Slate

Slate suitable for roofing is quarried near Zwarttruggens in the western Transvaal. It is not a true slate, but none the less cleaves very readily along its bedding planes, which are generally covered with minute glistening flakes of white mica.

A more thickly bedded flagstone is quarried at Pretoria and is extensively used for curbing and paving.

SANDS

Sands suitable for making ordinary grades of glass-ware occur at Zandfontein north-west of Pretoria; at Wonderboom north of Pretoria, and Silverton and Pienaarspoort east of Pretoria; also at Vereeniging and the Tweefontein colliery; in Zululand and at Philippi on the Cape Flats near Capetown.

Good moulding sand occur at many localities, notably at Vereeniging and Pretoria, and near Somerset West and Pretoria.

Sands suitable for building purposes and concrete have a wide distribution, but there is little information available in regard to their texture and quality.

CLAYS

Ordinary clays suitable for brick and tile making have a wide distribution in the Union, and are utilized at many localities in the Transvaal, Natal and the Cape Province. Some of the best bricks produced in the country are, however, made from a mixture of crushed shale and clay, or from crushed shale alone. Shale belonging to the Upper Dwyka and Pretoria series is used for this purpose.

Kaolin

There are important deposits of Kaolin on the farm Kranzfontein south of Boons siding on the Krugersdorp-Zeerust railway; near the White River Settlement in the Barberton district; at Grahamstown; close to Padleys station on the Durban-Maritzburg railway; on the Cape Flats and in Namaqualand. The Kranzfontein and Grahamstown kaolins are being successfully employed for making pottery.

Fireclay

Fireclay occurs at a number of localities in the Dwyka and Eccca series. Dwyka tillite mixed with shale of the Eccca and of the Witwatersrand is used in places for making fireclay goods.

The best known deposits are at Boksburg, Olifantsfontein and Vereeniging in the Transvaal, where there are important establishments for the manufacture of refractory wares.

Pottery Clay

Most of the coal measure clays are suitable for pottery work. A deposit of these was worked at Olifantsfontein, between Pretoria and Johannesburg, and very excellent articles of domestic potteryware were produced. Owing, however, to the cheap price, and great variety of imported pottery, these works have been closed down for some years.

Common Clay

Good common clay for brickmaking is almost universal throughout the Union, and near the large centres beds of shale have been found giving a uniform and satisfactory clay for pipes, tiles, etc., which are now being produced in the Union on a large scale, and which are competing as roofing materials with the formerly universal galvanized iron.

The available returns show that the value of clay products manufactured in the Union increased from £939,388 in 1924-25 to £1,162,244 in 1926-27.

SULPHUR

The pyritic concentrates of certain gold mines in the Sabie and Pilgrims Rest districts of the Transvaal constitute at the present time the only South Africa source of sulphur for the manufacture of sulphuric acid. The bulk of the concentrates come from the mines and the

Sandstone Reef at the top of the Black Reef Series. The concentrates contain about 45 per cent. of sulphur and up to one ounce of gold per ton. The sulphur is paid for at a fixed rate per ton, and the gold at full value minus a small percentage to cover extraction.

At Areachap, 23 miles north-west of Upington, in the Cape Province, a series of big lenses of cupriferous pyrite occur along a zone of fissure striking east 30° south. Large amounts of pyrite are apparently available, but the occurrence is so inaccessible that the pyrite cannot compete on an economic basis with imported sulphur.

The total production of pyrites in the Union to the end of 1928 is valued at £69,646.

TALC

Small amounts of talc have been produced for some years in the Barberton district of the Transvaal, where there are extensive occurrences of both massive and foliated talc, from a belt of ancient serpentines and basic schists of the Jamestown Series that extends for about fifty miles from the Drakensberg eastward.

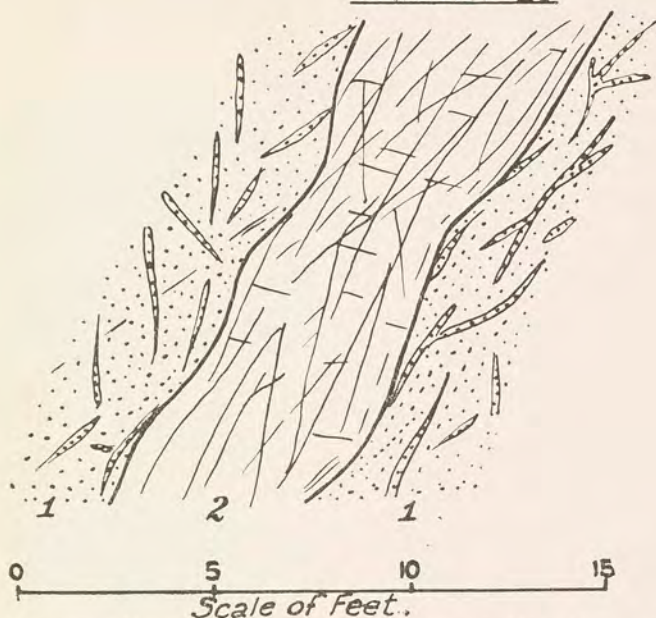
A few years ago an important deposit of talc was opened on the north sides of an east-west ridge on the farm Strathmore, 3 miles east of Kaapmuiden station. Green foliated talc occurs in a body from 5 to 6 feet and up to 20 feet wide striking north-west and dipping steeply north-east. The country rocks are highly altered serpentines and basic talcose schists through which run many irregular veins of magnesite. (Figure 23.) The body persists in depth to 400 feet down the dip and along the strike for 200 feet. Hall believes that the talc was formed from ultra basic schists by hydration and carbonation brought about by surface waters.

Talc occurs in three varieties: (1) clear pale apple green foliated talc of schistose texture and of high grade forming the mass of the main lode; (2) massive green talc, which differs from the other in being massive rather than schistose. It occurs in small amounts only; (3) steatite, an impure variety of talc, formed on the south side of the same ridge.

The body of high-grade talc lies high on the hill side and has been developed by open-casts and an adit driven to meet the talc lode.

PREPARATION

After a certain amount of hand-sorting has eliminated inferior rock, the talc is broken by hand to lumps up to 4 inches across and fed to a Blake crusher that breaks

FIGURE 23

Section across the main talc lode, Kaapmuiden. 1 Altered serpentine and basic talcose schist. 2 Green foliated talc lode.

(After A. L. Hall.)

them to $\frac{1}{2}$ an inch and less. A conveyor belt, which allows, of more sorting carries the material to a pulverizer where the fines are blown out by a 600 cubic feet per minute current of air and go to a settling chamber. The oversize goes to a second pulverizer, and thence to a revolving cylinder covered with silk of 160 linear mesh, and back to the pulverizer until the whole product has become a fine powder. The products are graded according to fineness from 100% through 350 mesh to 60% through 200 mesh.

The steatite is cut into flat rectangular and square slabs and sold in that form. Talc in the form of powder, has a great variety of uses, amongst them that of filler for paper and rubber, toilet powder, etc., Steatite is used for making engineer's chalk and for heat and electric insulators. Hall estimates the probable reserves of talc in this deposit at from 21,000 to 25,000 tons and possible ore on the order of 400,000 tons.

The total value of the talc produced in the Union is given as £21,242, of which over 99 per cent. came from

the Transvaal. The production for 1927 was 324·250 tons; 596·356 tons in 1928 and 289·573 tons valued at £1,423 in the first six months of 1929.

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CHAPTER X

GOVERNMENT AID AND CONTROL

The Government of the Union, through its Department of Mines and Industries, supervises and controls the mining industry. Laws have been framed to regulate the prospecting for, and the mining of, minerals from alluvial and lode deposits in various provinces of the Union, to regulate ownership and marketing of precious stones, and to safeguard the health and lives of persons employed in mines and in works connected with mines.

The officials employed by the Department to enforce the regulations are men of integrity and professional standing and their work is done effectively and with a minimum of friction. It is recognized by the white miners and by the industry that the strict enforcement of regulations to prevent sickness and accident is necessary in an industry where the bulk of the workers are natives, whose mentality and sense of responsibility is not highly developed.

There has been a certain amount of State aid to mining, but in this regard much remains to be done. If one considers the comparatively large revenue that is received by the Government from the mining industry, the amount of technical assistance that is given towards investigational work upon ore deposits and mining and metallurgical problems is comparatively small. The Geological Survey, which is the most suitable institution for investigating our mineral resources, receives so small an appropriation that it cannot do the required amount of fundamental areal geology that is essential for the healthy growth of a mineral industry. The Survey is an efficient organization and has done much good work, according to its means. If this bureau were provided with sufficient funds it could undertake detailed work on certain ore deposits, broad surveys of non-metallie mineral deposits, and the establishment and operation of laboratories for testing the suitability of certain minerals and rocks as structural materials, to the great advantage of all those engaged in the mineral industry.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

The proposed establishment of a Fuel Resources Institute to investigate the coal resources of the Union is a step in the right direction. It is hoped that with the commencement of greater activity in the opening up of our base metal and non-metallic mineral resources, further technical assistance will be forthcoming.

In the following chapter sections are devoted to the prevention of accidents in mines, State aid to mining and the mineral laws of the Union.

ACCIDENTS ON MINES.¹

The following table shows the progressive returns year by year for accidents, fatal accidents, deaths, and death-rates, on the various classes of mines in the Union, but does not include statistics of alluvial diamond diggings where the relative labour figures cannot be obtained accurately:—

ACCIDENTS AND DEATH-RATES ON MINES, FROM 1911.

Year.	Total Number of Accidents.	Fatal Accidents.	Deaths during the Year.	Death-Rate per 1,000 Employees.			
				Metal- liferous Mines.	Coal Mines.	Diamond Mines.	All Mines.
1911	2,897	882	1,061	3.89	1.96	2.24	3.51
1912	3,027	785	987	3.65	2.11	1.48	3.22
1913	3,200	793	992	0.57	2.88	2.24	3.31
1914	2,631	593	743	0.09	1.90	1.55	2.80
1915	2,552	608	776	3.05	2.05	0.40	2.93
1916	2,769	635	808	2.99	2.05	0.67	2.79
1917	2,631	545	664	2.53	2.16	1.10	2.37
1918	2,651	498	612	2.43	1.60	1.19	2.23
1919	2,945	516	607	2.36	1.83	1.88	2.25
1920	3,314	550	613	2.34	2.41	0.92	2.21
1921	4,947	434	525	2.14	1.65	1.06	2.03
1922	3,361	361	437	1.83	2.41	0.53	1.88
1923	3,913	504	637	2.44	2.70	1.29	2.42
1924	4,321	524	667	2.49	2.31	2.34	2.45
1925	4,826	506	600	2.27	2.35	1.15	2.21
1926	4,753	536	735	2.13	5.69	1.27	2.54
1927	7,141	625	742	2.62	2.45	1.50	2.52
1928	8,484	586	671	2.19	2.88	1.22	2.21

Full and detailed statistics of accidents and death-rates are given in the annual reports of the Government Mining Engineer.

¹ Contributed by F. C. Vaughan, Department of Mines of the Union of South Africa.

The number of accidents occurring on mines in the Union is large, but recently only about one-twelfth of the accidents reported were attended with fatal results, and in such cases it is the exception for an accident to involve more than one death, the proportion of fatal accidents to deaths being as 1 is to 1.25.

There has been a strenuous campaign carried on against accidents in mines, more particularly on the Witwatersrand, since the inauguration of the Prevention of Accidents Committee of the Rand Mutual Assurance Company. This Committee met for the first time in 1914, under the chairmanship of the Government Mining Engineer, and its activities have resulted in the introduction of additional safety precautions, and a marked diminution in the loss of life in mining operations.

If we take the Witwatersrand Gold Mines only, which employ seventy per cent. of the total labour on mines in the Union, and compare the ten years 1908 to 1917 with the ten years 1918 to 1928 (omitting the year 1922 when the industry was disorganized by the strike), it will be found that the average number of deaths from accidents each year has decreased from 764 to 497, and the average death rate per annum per 1,000 persons employed has declined from 3.75 to 2.47.

If we compare the number of accidents with the amount of work performed, for the same mines and the same periods, it is found that the average number of deaths per one million tons of rock hoisted has been brought down from 27.25 to 15.87, and the number of deaths per one million lb. of explosives used from 24.99 to 15.21.

While the figures quoted tend to show that fatalities resulting from preventable accidents have been largely eliminated, it is found upon closer analysis that, although there has in recent years been an improvement in this respect, about one quarter of the fatal accidents can still be attributed to preventable conditions such as defective plant or carelessness on the part of the supervising authority or the injured party.

The following statement shows the comparative percentages of fatalities allocated to each cause, and is based on the findings of the government mining inspectors at the statutory enquiries into accidents:—

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

CLASSIFICATION OF CAUSES OF FATALITIES ON ALL MINES IN THE UNION

Percentages of total Deaths.

Year.	1 Danger inherent to mining or Misadventure %	2 Defective Plant or Material. %	3 Fault of Injured Person. %	4 Fault of Management. %	5 Fault of Gangers. %	6 Fault of Others. %	7 Joint Fault of parties referred to in 3, 4, 5 and 6. %
1911	58.5	1.9	22.2	1.6	7.9	5.0	2.9
1912	53.1	4.8	18.6	1.1	12.6	6.0	3.8
1913	57.7	4.1	12.9	3.7	11.9	6.4	3.3
1914	58.1	1.2	11.8	3.9	14.3	6.9	3.8
1915	62.0	1.2	12.2	3.1	12.1	3.3	6.1
1916	55.1	1.1	10.8	4.1	15.0	9.0	4.9
1917	68.2	2.7	8.3	1.3	11.0	4.1	4.4
1918	74.2	1.5	9.6	1.3	5.7	4.4	3.3
1919	64.9	1.3	12.3	3.4	9.1	5.6	3.4
1920	69.8	1.1	9.8	1.8	9.6	4.6	3.3
1921	71.2	1.9	9.5	1.5	8.6	5.0	2.3
1922	65.2	2.5	13.3	2.1	9.2	5.0	2.7
1923	71.0	2.0	10.8	1.7	7.1	3.9	3.5
1924	65.8	2.1	11.9	2.7	10.2	4.3	3.0
1925	64.8	3.2	11.6	2.0	10.3	4.9	3.2
1926	71.6	2.6	9.8	2.3	6.8	4.6	2.3
1927	69.4	2.7	9.7	1.3	8.4	5.8	2.7
1928	67.9	1.8	8.9	3.0	6.0	9.1	3.3

The table shows that although preventable accidents have diminished in some measure, there has been a relative increase in accidents which are due to the ordinary inherent mining hazards, such as falls of rock, and the danger from this class of accident, becomes more ominous as the workings are carried deeper and grow in extent.

This is partly borne out by the fact that for the first of the ten yearly periods quoted above the number of fatalities due to fall of rock was 31 per cent. of all deaths, whereas for the last ten years it has been increased to 39 per cent.

The following diagram illustrates the constant menace from accidents that are brought about by falls of ground. It also shows there has been a material reduction in the death rate from most of those accidents where the human factor plays an important part in the occurrence.

GOVERNMENT AID AND CONTROL

In the following table the number of deaths year by year in all mines in the Union is classified under the various causes:—

Year.	Fall of Ground.	Explosives.	Struck by cage, Traveling in shafts, etc.	Falling of Material.	Falling in Shafts and Excavations.	Trucks and Tramways.	Machinery.	Miscellaneous.
1911	333	228	103	92	71	64	49	121
1912	316	210	97	100	64	66	30	104
1913	315	240	82	85	61	50	39	120
1914	275	156	64	60	47	44	29	68
1915	279	167	77	66	49	52	18	68
1916	290	168	57	63	39	74	22	95
1917	273	104	34	53	45	56	24	75
1918	226	65	40	63	33	69	19	97
1919	204	75	47	65	40	67	22	87
1920	237	58	46	83	25	69	18	77
1921	227	39	29	51	32	56	25	66
1922	175	40	34	42	12	55	11	68
1923	301	62	33	42	19	79	22	79
1924	274	106	36	55	18	75	21	82
1925	228	121	39	40	17	61	22	72
1926	244	83	44	38	17	86	16	207
1927	338	93	38	46	22	98	16	91
1928	272	68	46	48	19	99	20	99

If the total deaths are divided into those of white persons and those of coloured it is found that the loss of life among white employes averages about 58 per annum as compared with 660 among coloured persons. The proportion between the two figures follows very closely the ratio between the relative numbers engaged in mining, for the average death rates work out at 2.08 for whites and 2.62 for coloured. When the great difference in the mentality of the two classes of labour is considered, and one remembers the various kinds of risk to which persons working underground in mines are exposed, the discrepancy between the two death rates is not excessive, and it speaks well for the care which is bestowed in safeguarding the ignorant native.

STATE AID TO MINING²

The moneys made available by Parliament for district mining development from time to time were chiefly expended in the making and repairing of roads and drifts in mineral localities in order to assist a mining community as a whole.

Since the financial year which ended on March 31, 1928, however, no sums have been expended by the

² Contributed by the office of the Government Mining Engineer, Department of Mines and Industries.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

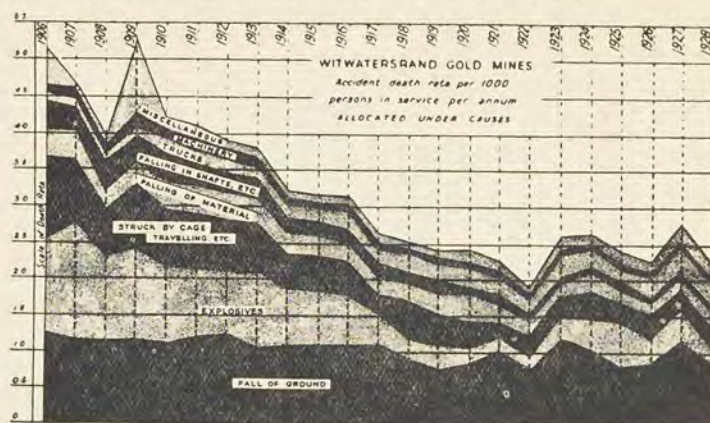


FIGURE 24.

(After F. C. Vaughan.)

Department of Mines and Industries in respect of the making and repairing of roads, as it was considered that this work should be performed by the various Provincial Councils.

The Department has, however, provided a number of boreholes with pumps in the Leydsdorp division of the Pietersburg district, Transvaal, for the purpose of supplying water to prospectors and others in that area, and the maintenance of some of these boreholes and pumps is still a charge against the vote of the Department of Mines and Industries. Others, which fall on land which has been disposed of to settlers are maintained by the settler in return for the right to take such water therefrom as he may require.

Assistance to the mining industry is also afforded in other ways. The identification of minerals for prospectors is undertaken free of charge by the Geological Survey, and the analysis of prospectors' samples is performed at the Government laboratories at Johannesburg and Cape Town under a very reasonable tariff of charges. Samples either for identification or analysis are conveyed by post or rail free of charge.

In cases where prospecting claims are being worked remission of the Government's share of licence money is granted, provided that a certain amount of work has been done on the claims, and, in the case where the claim-holder is a company, that no dividend has been paid to shareholders in respect of the last financial year.

The Government also contributes towards the expenses of the Miners Training Schools on the Witwatersrand, which were established with a view to the training of youths for subsequent employment on the mines.

The Sabie Gorge hydroelectric undertaking was established by the Electricity Supply Commission for the purpose of supplying electric power to the mines in the Sabie area of the Pilgrims Rest mining district.

The Government has also rendered assistance in the direction of the establishment of permanent industries by engaging the services of experts from overseas, who have investigated and reported on the possibilities of iron and petroleum in the Union. The Department has further helped to direct public attention to specific mineral possibilities by the publication of memoirs or contributions in official or other publications.

MINERAL LAWS OF THE UNION³

The mining laws of the Union are administered by the Department of Mines and Industries which has the supervision and control of the mining industry.

UNION LEGISLATION

Except in regard to precious stones the mineral laws of the Union have not yet been consolidated, and the laws passed by the various Colonial Governments, prior to the constitution of the Union, are still in force in the various provinces.

Mines, Works and Machinery Act, 1911

The Actual working and inspection of all mines, works and machinery throughout the Union is, however, governed by the Mines and Works Act of 1911 as amended by the Mines and Works Act 1911 Amendment Act 1926. Under this Act, the supervision of all mines, works and machinery is placed under the Government Mining Engineer and the Inspectors of Mines, Inspectors of Machinery and Inspectors of Explosives, responsible to the Government Mining Engineer.

The Act lays down the hours for underground labour and provides for the trial of persons charged with breaches of the regulations or rules and for enquiries by inspectors of mines into accidents.

The regulations framed under the Act deals in detail with all the various questions appertaining to the safety of persons employed on mines and works.

Precious Stones Act, 1927

Prospecting, digging and mining for precious stones in the Union are now governed by the Precious Stones Act 1927, by which the various laws dealing with these matters passed by the Colonial Parliaments prior to the constitution of the Union are repealed. This Act reasserts the principle that the right of mining for and disposal of precious stones is vested in the Crown, sets out the conditions

³ Contributed by the office of the Government Mining Engineer, Department of Mines and Industries.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

under which prospecting, digging and mining for precious stones may take place and prescribes the rights accruing to owners and surface owners of land on which precious stones have been discovered. It provides for the award of discovery rights to discoverers of precious stones, for the proclamation of mines and alluvial diggings, the methods of distributing claims on the latter, and for the establishment of State diggings. It further confers on the Governor-General wide powers to control the diamond industry by means of regulations, and makes provision whereby he may control the output from alluvial diggings.

The Act further makes provision for the establishment of Diggers' Committees, the granting, refusal or cancellation of diggers certificates and generally deals with all matters relative to the working and administration of diamond mines and alluvial diggings.

The Diamond Control Act of 1925 is a measure passed to enable the Government to control the production and sales of diamonds produced from diamond mines as distinct from alluvial diggings. The provisions of this Act as well as the provisions in the Precious Stones Act 1927 enabling the Governor-General to control the output from alluvial diggings were considered necessary to guard against the dislocation of the diamond market through over-production.

It has not been found necessary, however, to take any administrative action under these provisions owing to satisfactory agreements in regard to production and sales having been entered into between the various large producers of diamonds in the Union of South-West Africa and between these producers and the Diamond Syndicate.

The Reserved Minerals Development Act 55 of 1926 was placed on the Statute book in order to facilitate the exploitation of mineral deposits on land held under titles containing a reservation of mineral rights to the Crown. Briefly the effect of the Act is to confer upon the surface owner, or in case of land not finally alienated from the Crown, the lessee or licensee of such land, the exclusive right of prospecting subject to his obtaining a prospecting licence in terms of the provisions of the Act.

Upon the discovery of minerals in payable quantities provision is made for the granting of discoverers' rights, but in the case of land not finally alienated from the Crown no discoverers' rights may be granted until such time as a Crown Grant in respect of the land has been issued.

The surface owner is also given rights to obtain a mineral lease on his farm subject to the payment to the Government of a share of the profits derived from the mining of such minerals.

TRANSVAAL PROVINCE

Of the Provinces of the Union, the Transvaal has so far proved the most productive in minerals. The law dealing with prospecting and mining for precious and base metals is the Transvaal Act No. 35 of 1908 (commonly known as the Gold Law) which came into operation in 1909, amending and consolidating previous laws passed by the Republican Government.

The Act adheres to the principle adopted by previous laws that the right of mining for and disposing of all precious metals is vested

in the Crown, and that the ownership of and the right of mining for and disposing of base metals on Crown or private land is vested in the owner of such land.

Precious metals are defined as gold and silver, and any other metal (not being a base metal) which may be declared as such by proclamation. By Proclamation No. 180 of 1923, platinum was declared to be a precious metal.

Base metals are defined as quicksilver, iron, lead, copper, tin, zinc, cobalt, nickel, arsenic, manganese, antimony, bismuth, sulphur, coal and graphite and any other mineral substance for the exploitation of which no special provision is made by law and these may be mined by the owner of the mineral rights subject only to the Act and regulations dealing with the working of mines.

The Precious and Base Metals Act 1908 further makes provision for prospecting for precious metals and for base metals where these occur on Crown land, for the granting of discovery rights and the proclamation of public diggings. It specifies the rights which accrue to the owner of the land and the owner of the mineral rights in the event of proclamation of a public digging, and lays down the manner in which the undermining rights on a public diggings may be disposed of. This may be done in three ways:—

- (1) The public digging, or any portion of it, may be declared to be open to the public for the pegging of claims.
- (2) The exclusive right to mine on any portion of the digging the undermining rights of which have not already been otherwise disposed of may be leased to any person.
- (3) With the previous sanction of Parliament, a State mine may be established on any portion of the digging.

On any portion of a public digging which has been declared open to pegging, claims each in extent 400 x 150 Cape feet may be pegged under the authority of a license called a "prospecting license." Such a license is obtainable from the Mining Commissioner by any white person of the age of 16 years or upwards on payment of the prescribed fees, which are as follows:—

- (1) Precious metals: 2s. 6d. per month per claim on Crown land; 5s. per month per claim on private land.
- (2) Base metals—Crown land only: 1d. per month per claim for the first year and thereafter 6d. per month per claim.

In the case of precious metals, however, as soon as use has been made of machinery for the crushing or treatment of ore, or a claim has been sufficiently developed to permit of the extraction of ore therefrom, the license holder must, before he is entitled to win precious metals from any such claim, convert his prospecting license into a diggers license, in respect of which the sum of £1 per month is payable, whether on Crown or private land.

In the case of private land one half of the license moneys received by the Mining Commissioner is paid to the owner of such land.

In the event of the license moneys in respect of any claim being allowed to fall three months in arrear, the claim lapses to the Crown and may be dealt with by the Governor-General in any one of the three ways prescribed for the disposal of undermining rights on a public digging.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

On proclamation of a public digging on private land, the surface rights of the owner are suspended and the Act makes provision for the granting to the owner on proclamation of his farm of certain surface reservations, and for the granting of surface rights at any time for mining and other purposes.

Dealing in unwrought precious metals is also governed by this Act, which makes provision for the control thereof.

The Transvaal Mining Leases and Mineral Law Amendment Act No. 30 of 1918, while a Union statute, is an amendment to the Transvaal Act No. 35 of 1908 and is applicable only in the Transvaal.

It lays down the conditions under which the undermining rights of proclaimed land may be disposed of by leasing, and repeals section 46 of Act 35 of 1908, which formerly dealt with this matter.

It also contains several amendments to the provisions of Act 35 of 1908 in regard to administrative matters apart from mining leases.

PROVINCE OF THE CAPE OF GOOD HOPE

The law in force in the Cape Province is the Precious Minerals Act No. 31 of 1898, which is amended by the Precious Minerals Amendment Act No. 45 of 1905 and the Mineral Law Amendment Act No. 16 of 1907.

There is no provision in these Acts reserving to the State the right of mining for and disposing of minerals but the Acts apply only to land—the title to which contains a reservation of mineral rights to the Crown. The majority of Cape titles, however, contain a reservation of precious minerals to the Crown and in many cases base mineral rights are also reserved. Where the base mineral rights are reserved the exploitation of such base minerals is governed by the Reserved Minerals Development Act No. 55 of 1926, previously referred to under the heading of Union Legislation, since the mineral laws of the Cape Colony only dealt with base minerals where such occurred on Crown land.

The right of a surface owner of private property to prospect thereon without a license or to permit any duly licensed prospector to prospect thereon is recognised.

Prospecting licenses are issued by Civil Commissioners and cost 2s. 6d. per month for precious minerals and 1s. per month for base minerals.

Precious minerals are defined as gold, silver and platinum, and base minerals as asbestos, building stone, cinnabar, clay, coal, cobalt, copper, crocidolite, gypsum, iron, lead, manganese, magnesite, nickel, natural gas, oil, salt, slate, tin and such other minerals not being gold, silver or platinum, as may from time to time be declared by proclamation to be base minerals.

Up to the time of writing, the following minerals have been proclaimed as base minerals: steatite, limestone, corundum (ruby), oil shale, molybdenum, tungsten, antimony, mica, soapstone, and graphite.

Provision is made for the grant of 50 claims—150 feet x 800 feet—as discoverers' rights in the event of the discovery of precious minerals in payable quantities, and in the case of the discovery of base minerals on Crown land in workable quantities, the discoverer is entitled to obtain a base mineral lease over an area not greater than 1,000 acres in extent.

GOVERNMENT AID AND CONTROL

NATAL PROVINCE

The law in force in the Natal Province is the Natal Mines Act No. 43 of 1899.

Under this Act any person may prospect for minerals on Crown lands without taking out a license, so long as such prospecting is confined to a general examination of the surface and no excavations are made. He may also peg off not more than four prospecting claims, provided that he takes out licenses therefor within 14 days. There are three classes of claims, namely: alluvial, metal and mineral.

On private land the owner may prospect without taking out a license, but may not peg a claim without first taking out a license therefor. There is no limitation as to the number of claims which may be pegged by an owner.

No person other than the owner may prospect on private land without the consent of the owner, unless the Deputy Commissioner of Mines has notified the owner of his intention to issue prospecting licenses in respect of his land to some other person, and the owner has not objected, or his objections have been overruled by the Deputy Commissioner. An appeal lies to the Minister against the decision of the Deputy Commissioner in this respect.

The fee for a prospecting claim license is 1s. per claim for three months and the fee for registration of prospecting claims is 5s. per claim.

No mining operations may be carried on until a mining claim has been pegged, unless special permission is obtained from the Commissioner of Mines.

The fee for a mining claim license is £1 per month for a metal mining claim and £2 per month for an alluvial or mineral mining claim.

Prospecting on Native Trust lands may be carried on by virtue of a license, issued under a permit granted by the Chief Native Commissioner for Natal, or under a letter of permission granted by the District Native Commissioner for Zululand.

ORANGE FREE STATE PROVINCE

The laws in force in the Orange Free State are the Mining of Precious Minerals Ordinance No. 3 of 1904, as amended by Act No. 9 of 1908, and the Mining of Base Metals Ordinance No. 8 of 1904.

No person, other than an owner of private land on his own land, may prospect without taking out a prospecting license and no person may prospect on private land without the consent of the owner.

Prospecting licenses are issued by Resident Magistrates, except in the case of base metals on Crown lands in which case prospecting and mining can be carried on under an agreement with the Governor-General.

The fee for a prospecting license, except for base metals on Crown land, is five shillings per month, and a registration of 5s. in the case of precious metals and 2s. 6d. in the case of base metals, is payable.

Precious metals are defined as gold and silver and such other precious metals as may be declared as such by proclamation. Platinum has been proclaimed as a precious metal.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

Base metals are defined as tin, copper, iron, zinc, lead, cinnabar, coal, petroleum, oil shale, sulphur, chloride of sodium (salt) and such other metals or minerals other than gold, silver or precious stones, as may be declared as such by proclamation. Molybdenum, tungsten, antimony, and their ores have been proclaimed as base metals.

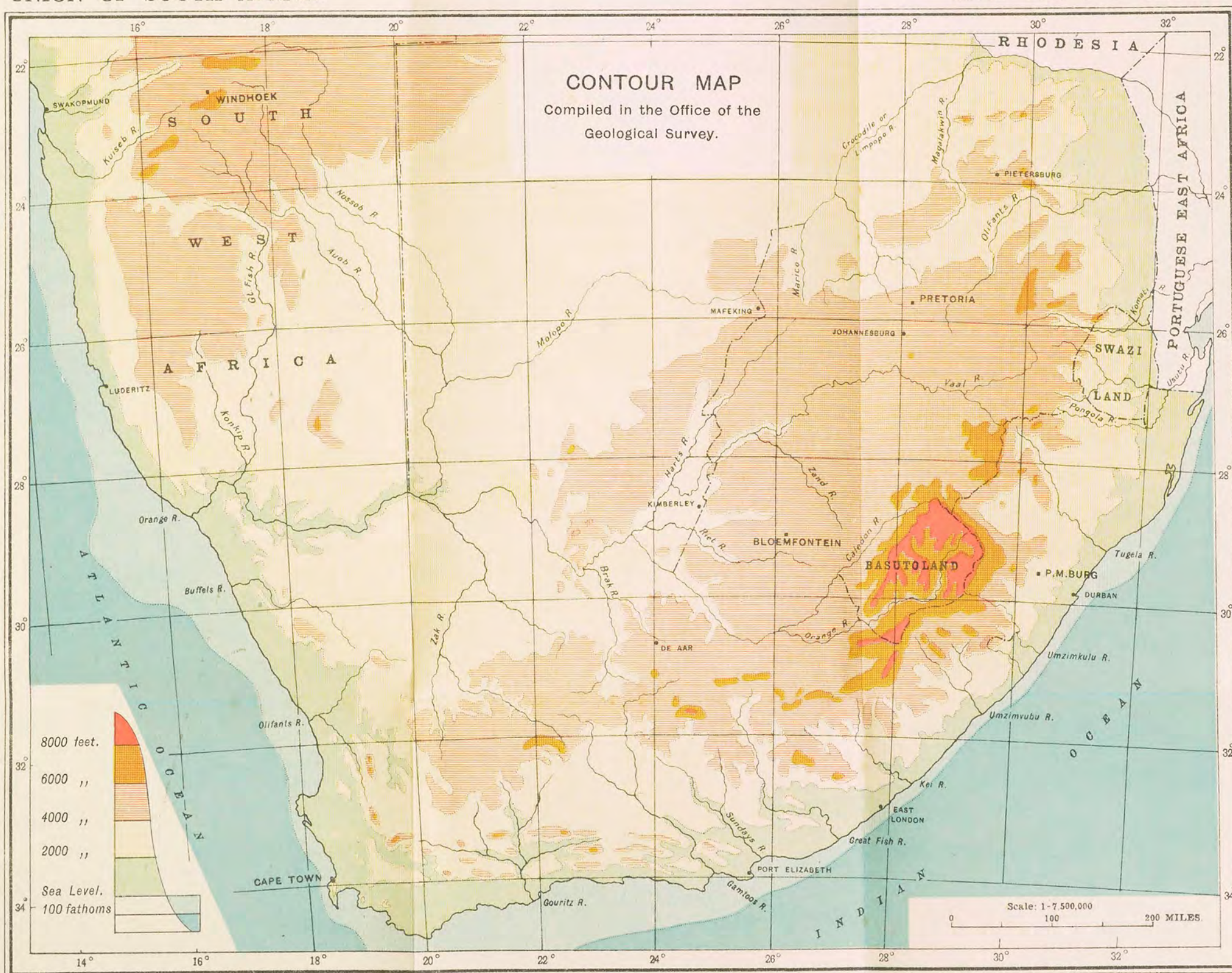
Provision is made for the granting of discoverers' rights and in the event of it being decided to proclaim a public digging for precious metals, the owners' rights are also provided for.

When private land has been proclaimed a public digging and after the discoverers' and owners' rights have been satisfied, the remainder of the proclaimed area shall be thrown open to the public for pegging of claims under license. Any white person over the age of eighteen is entitled to obtain a claim license from the Magistrate on payment of a license fee of 5s. per month per claim and a registration fee of 5s. for every claim or block of claims issued to one holder. No license holder is entitled to peg off more than 50 claims in a reef digging or three claims in an alluvial diggings.

The size of a reef claim is 60,000 square feet, and that of an alluvial claim 150 feet square.

UNION OF SOUTH AFRICA.

UNIE VAN SUID-AFRIKA.



CENSUS 1.

Drawn in the Geological Survey Office Pretoria.

MINERAL DEPOSITS OF THE UNION OF SOUTH AFRICA

Base metals are defined as tin, copper, iron, zinc, lead, cinnabar, coal, petroleum, oil shale, sulphur, chloride of sodium (salt) and such other metals or minerals other than gold, silver or platinum.

